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THE CHEMICAL COMPOSITION AND PHYSICAL PROPERTIES OF STEEL RAILS.[1]

By C. B. DUDLEY, Ph. D., Chemist, Penna. R. R. Co.

In the spring of 1877, the Pennsylvania Railroad Company became so dissatisfied with the average life and wear of the steel rails it was then able to procure, that it determined to make an investigation into the chemical composition and physical properties of steel rails, with a view, first, to answering the question why one steel rail has to be removed from the track after, perhaps, 8 months' service, while another lasts 10 years; and, secondly, if this investigation succeeded in throwing light on this important subject, to use this information in securing better rails in the future. The results of that investigation are contained in the following report. In presenting this report to the Institute of Mining Engineers, which I am permitted to do by the kindness of the officers of the Pennsylvania Railroad Company, it has been thought best to retain the form and style in which the report

[1] A paper read before the October (1878), meeting of the American Institute of Mining Engineers.

was written. For although the report was originally written for the officers of the Pennsylvania Railroad Company, and, consequently, the discussion of details made a little more full than if it had been written as a scientific paper, yet this very fullness of detail may not be amiss in a field where knowledge is so urgently needed.

REPORT.

THEO. N. ELY, ESQ., *Supt. Motive Power, Penna. R. R. Co.*

Dear Sir:—I have finished the examination of the subject of steel rails in connection with their chemical constitution, physical properties, and wear, which has occupied my attention and study, more or less constantly, for six months past, and beg leave to present thereon the following report:

The question which led to, and has followed in all its details, the investigation embraced in this report, is: How shall the Pennsylvania Railroad Company obtain steel rails which shall give a satisfactory wear and be uniform in quality?

In order to understand the attempt which has been made to answer this question, it will be necessary to state a few preliminary principles. It seems to be agreed among metallurgists, that the quality of a piece of steel depends upon two sets of circumstances: 1st, upon its chemical constitution, and 2d, upon the treatment which the metal receives either during or after its manufacture. In other words, a piece of steel of certain chemical constitution and treatment will have certain physical qualities of strength, elasticity, ductility, power to resist wear, etc.; or again, a different chemical constitution and treatment will give a piece of steel which will differ in one or more of these respects from the first; the former being possibly more valuable for rails, the latter for cutting-tools.

Now it is to be confessed at the outset, that our knowledge of these two sets of circumstances, viz., the chemical constitution and treatment necessary to secure such a piece of steel as is desired, is far from being all that could be wished for. Nevertheless, some things are known, and the work which is described below is an attempt to add to our knowledge in this respect, with regard to steel rails.

Now inasmuch as all our steel rails are made at present by the Bessemer or Pneumatic process, and inasmuch as the conditions of successful working of this process are pretty well understood, it is assumed that the *treatment* which the steel receives during manufacture is constant or always alike. That this is an actual fact in prac-

tice, is probably not true. The carelessness of workmen, and the want of proper appliances, may at times cause more or less variation in the treatment which the successive "blows" or heats in the Bessemer converter receive. These variations are, however, undoubtedly small, and where care is taken, and the Bessemer process given its full chance, the want of uniformity of product, so far as that uniformity depends upon treatment or method of manufacture, should be very small. I would not be understood as saying, however, that I think the Bessemer process has reached its full development, or is incapable of further improvement. The difficulty of obtaining solid ingots, whether it is better to use the bottom or top cast, whether the slag is all separated before casting, at what temperature the rail should go through the rolls, and especially the last pass, and how to get this temperature, are questions still awaiting solution, and I think it undoubted, that to one or more, or possibly all combined, of these uncertainties are due some of the anomalies which are often met with in steel.

Nevertheless, assuming, as has already been stated, that the Bessemer process, as at present understood and worked, is capable, in careful hands, of turning out a moderately uniform product, so far as that uniformity depends upon *treatment* or method of manufacture—which is undoubtedly the case—the question how to obtain a good rail becomes one as to the chemical composition of the steel, and this is the part of the problem to which I have devoted some labor and study. We are fortunately, however, not entirely dependent for uniformity of product, so far as that uniformity depends upon treatment or method of manufacture, upon the uniformity with which the rail manufacturers work the Bessemer process. Just here comes in the sphere for appropriate physical tests and inspection. For example, it seems clear to me that if a "blow" or heat in the Bessemer converter is badly treated at any point during the manufacture, so that the steel is spoiled, appropriate physical tests and inspection will reveal this fact, and thus enable us to protect ourselves by rejecting that "blow." So that the question with which we started, viz., How shall the Pennsylvania Railroad Company obtain steel rails which shall give satisfactory wear and be uniform in quality? seems to be resolved into two others, viz., (1) With the present known metallurgical methods in the Bessemer process, what chemical composition shall the Pennsylvania Railroad Company prescribe for its rails? and (2) What physical tests and inspection shall it apply to

secure uniformity of product? What follows is an attempt to answer these questions.

I.—As to Chemical Composition.

It is well known that there are six impurities which exist in nearly all iron and steel in greater or less amount, which are known to have important influences upon its quality, even in small quantities. These are carbon, phosphorus, silicon, manganese, sulphur and copper, and when we speak of the chemical composition of steel, we mean the amount of these various impurities which the steel contains. Steel, and especially pig iron contain other impurities, such as titanium, cobalt, nickel, arsenic, etc., but these are commonly disregarded in analysis because their amount is usually very small, and some of them are not known to have any influence upon the quality of the metal. A discussion as to the influence of these various impurities upon the quality of steel, will follow later. It is sufficient here to say, that almost the only effect that sulphur and copper are known to have on steel, is to render it what is technically known as "red short," that is, if a steel rail has too much sulphur and copper in it, it crushes in the rolls or flies to pieces, during manufacture. I am unable to find, anywhere, that sulphur and copper are said to have a deleterious effect on the wear or durability of a rail, and indeed, some metallurgists claim that they are advantageous in this respect. I have, therefore, not determined the sulphur or copper in the analyses given below, and would not recommend to prescribe any specifications in regard to them. We can safely trust the rail manufacturers not to give us rails containing too much sulphur and copper.

As to the other four impurities, the question now arises, how much of these various substances ought a good steel rail to contain? In order to answer this question, twenty-five pieces of steel rail have been carefully analyzed for carbon, phosphorus, silicon and manganese. The borings for analysis were taken out of the physical test pieces described below. The chemical work was all done in duplicate. The carbon was determined by combustion, working upon 7 grams, dissolving out the carbon with solution of the double chloride of copper and ammonium, and burning with chromate of lead. The phosphorus was determined by the molybdate of ammonium method, working upon 3 grams, and dissolving the steel in aqua regia. The manganese was determined by the bromine method, separating the iron as basic

acetate, and using acetate of soda as the precipitant. The silicon was determined in the usual way, working upon 10 grams, and dissolving in hydrochloric acid. The twenty-five samples of steel rail which were analyzed, have all been in actual service; some of them have broken in service, some have crushed in service, some have worn badly with short service, and some have endured long and hard service. The brands of steel represented in the series, are: Penn. steel, Cambria steel, Lackawanna Iron and Coal Co.'s steel, Cammel steel, Mersey steel, Ebbw Vale steel, and John Brown steel. It was thought that the series would represent, as fairly as a series of twenty-five samples could do, the actual results of good and bad service of rails on the Penna. R. R. Moreover, the samples were taken from all parts of the road, thereby rendering inoperative the influence of local causes upon the life and wear of the rails. If now the chemical composition of the good rails should show uniformity within narrow limits, while the chemical composition of the bad rails should likewise show uniformity; and if these uniformities of chemical composition in the good rails and bad rails should differ from each other, it would seem to be fair to conclude that the composition of the bad rails should be avoided, while that of the good rails should be adopted. That the good rails show a moderate uniformity of chemical composition, different from that of the bad rails, will be evident, I think, from an inspection of the analyses which follow.

One or two things more ought to be mentioned. In order to measure the value of a rail as to whether good or bad, the approximate tonnage which has passed over each of these pieces of rail has been computed; it being of course evident to all that the burden which a rail has sustained, even though approximately determined, is a much more accurate measure of its value than time of service. Again, position in a track, whether on a curve or on a straight line, and also whether subject to high speed or not, obviously have an influence upon the durability of a rail, and attention has been given to these points in estimating the value of a rail. It will be noticed in the tables which follow that the principle of measuring the value of a rail by the tonnage which has passed over it has not been strictly followed. The rails have been divided in the tables into two classes on this principle, viz.: *Those which crushed or broke in service* and *those which did not crush or break in service.* The former are regarded as bad rails and the latter as good rails. This principle of division

brings among the bad rails four whose tonnage is higher than the lowest tonnage of any rail among the good ones. But in view of the liability to accident which a broken or crushed rail may occasion, I think no one will claim that a rail which has broken or crushed in service should be classed among good rails, even though its tonnage may entitle it to be so rated.

Finally, as a means of determining whether good rails differed from bad rails in physical qualities, such as tensile strength, ductility, etc., and if it was found that they did so differ, as a means of enabling us to specify what physical tests the steel for our rails ought to stand, careful physical tests have been made of every piece of steel analyzed except two, the samples sent for analysis of these two being so small as to prevent physical tests being made. The physical tests were made on Prof. Thurston's Torsional Testing Machine, as being the best means of determining the largest number of physical qualities at a single test. A copy of the diagrams obtained in making these tests accompanies this report, and will be referred to later.

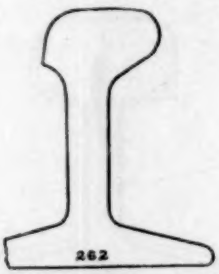
The history of each piece of rail analyzed, together with an outline sketch of the piece (one-third size) as it appeared when removed from the track, the tonnage, chemical analysis, and results of physical tests are given in order below. Following these is a tabulated statement of these results, and the conclusion drawn from them.

No. 32—*Broken near Edgar Thomsen Steel Works, first time train passed over it. Tonnage,* 0,000,000 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·359	Angle of Torsion	111°
Phosphorus	·156	Moment of Torsion	333
Manganese	·505	Tensile Strength at Rupture	78,255
Silicon	·035	" " " Elastic Limit	30,550
Total Hardeners	1·055	Percentage of Elongation	16·898
" in P. units	39·4	Proportional Ultimate Resilience	29·80

No. 83.—*In service from June,* 1875, *to September,* 1876; *sixteen months. Was in south track on* 9° *curve, just east of Columbia Tunnel. Broke in service. Tonnage,* 10,027,131 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·323	Angle of Torsion	106°
Phosphorus	·135	Moment of Torsion	340
Manganese	·522	Tensile Strength at Rupture	79,900
Silicon	·035	" " " Elastic Limit	33,135
Total Hardeners	1·015	Percentage of Elongation	15·509
" in P. units	36·4	Proportional Ultimate Resilience	28·60



No. 262.—*In service from October,* 1868, *to November,* 1876; *eight years, one month. Was in south track on* 9° *curve, just west of Valley Creek Bridge. Tonnage,* 44,636,201 *tons.*

Chemical Analysis.		Physical Tests.
Carbon	0·337	No Physical Tests were made, because of smallness of piece of rail sent.
Phosphorus	·056	
Manganese	·374	
Silicon	·056	
Total Hardeners	·823	
" in P. units	27·1	

No. 277.—*In service from September*, 1872, *to December*, 1876; *four years, three months. Was in south track on tangent, about midway between South Elizabeth and Linden. Broke in service. Tonnage*, 16,600,728 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·573	Angle of Torsion	101°
Phosphorus	·075	Moment of Torsion	433
Manganese	·853	Tensile Strength at Rupture	101,755
Silicon	·182	" " " Elastic Limit	43,005
Total Hardeners	1·688	Percentage of Elongation	14·169
" in P. units	52·9	Proportional Ultimate Resilience	36·81

No. 282.—*In service from August*, 1875, *to January*, 1877; *one year, five months. Was in single track near Marr's Run Station, on N. C. R. W. Broke in service. On tangent. Tonnage*, 4,535,318 *tons.*

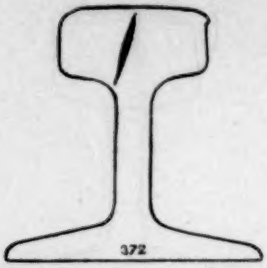
Chemical Analysis.		Physical Tests.
Carbon	0·354	No Physical Tests were made, because of smallness of piece of rail sent.
Phosphorus	·132	
Manganese	·552	
Silicon	·050	
Total Hardeners	1·088	
" in P. units	38·5	

No. 347.—*Broke after five days' service on New York Division. Tonnage,* 0,000,000 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·387	Angle of Torsion	67°
Phosphorus	·056	Moment of Torsion	306
Manganese	·670	Tensile Strength at Rupture	71,910
Silicon	·035	" " " Elastic Limit	30,550
Total Hardeners	1·148	Percentage of Elongation	6·467
" in P. units	36·6	Proportional Ultimate Resilience	16·65

No. 371.—*In service from July,* 1876, *to March,* 1877; *eight months. Was in single track, on Tyrone and Clearfield Division, south of Mount Pleasant. On curve* 16°. *Tonnage,* 2,741,056 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·386	Angle of Torsion	85°
Phosphorus	·127	Moment of Torsion	342
Manganese	·380	Tensile Strength at Rupture	80,370
Silicon	·053	" " " Elastic Limit	47,000
Total Hardeners	·946	Percentage of Elongation	10·223
" in P. units	35·8	Proportional Ultimate Resilience	24·68



No. 372.—*In service from July*, 1876, *to March*, 1877; *eight months. Was in single track on* 17° *curve, Tyrone and Clearfield Division, south of Mount Pleasant. Tonnage,* 2,741,056 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·416	Angle of Torsion	102°
Phosphorus	·155	Moment of Torsion	346
Manganese	·460	Tensile Strength at Rupture	81,310
Silicon	·034	" " " Elastic Limit	30,550
Total Hardeners	1·065	Percentage of Elongation	14·433
" in P. units	40·3	Proportional Ultimate Resilience	29·26

No. 373.—*In service from July*, 1876, *to March*, 1877; *eight months. Was in single track on* 20° *curve, Tyrone and Clearfield Division, south of Mount Pleasant. Tonnage,* 2,741,056 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·300	Angle of Torsion	102°
Phosphorus	·138	Moment of Torsion	281
Manganese	·412	Tensile Strength at Rupture	66,035
Silicon	·024	" " " Elastic Limit	25,850
Total Hardeners	·874	Percentage of Elongation	14·433
" in P. units	33·2	Proportional Ultimate Resilience	23·06

No. 388.—*In service from March*, 1867, *to March*, 1877; *ten years. Was in north track on a tangent near Ardmore Station. Tonnage*, 37,005,142 *tons.*

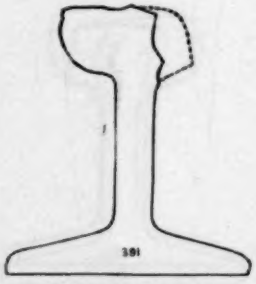
Chemical Analysis.		Physical Tests.	
Carbon	0·303	Angle of Torsion	120°
Phosphorus	·166	Moment of Torsion	322
Manganese	·316	Tensile Strength at Rupture	75,670
Silicon	·032	" " " Elastic Limit	31,725
Total Hardeners	·817	Percentage of Elongation	19·514
" in P. units	34·6	Proportional Ultimate Resilience	31·21

No. 389.—*In service from March*, 1872, *to April*, 1877; *five years, one month. Was on south track on a curve, one mile west of Huntingdon. Tonnage*, 34,333,639 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·343	Angle of Torsion	121°
Phosphorus	·127	Moment of Torsion	320
Manganese	·670	Tensile Strength at Rupture	75,200
Silicon	·036	" " " Elastic Limit	30,550
Total Hardeners	1·176	Percentage of Elongation	19·813
" in P. units	39·3	Proportional Ultimate Resilience	31·02

No. 390.—*In service from March,* 1868, *to March,* 1877; *nine years. Was in south track on* 2° *curve, on eastern slope of mountain. Pittsburg Division. Tonnage,* 47,332,411 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·291	Angle of Torsion	126°
Phosphorus	·057	Moment of Torsion	302
Manganese	·354	Tensile Strength at Rupture	70,970
Silicon	·068	" " " Elastic Limit	32,900
Total Hardeners	·770	Percentage of Elongation	21·337
" in P. units	25·9	Proportional Ultimate Resilience	31·95



No. 391.—*In service from June,* 1871, *to April,* 1877; *five years, ten months. Was in south track on* 4½° *curve,* 1700 *feet west of M. P.,* 84 *from Pittsburg. Tonnage,* 30,873,173 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·294	Angle of Torsion	117°
Phosphorus	·181	Moment of Torsion	333
Manganese	·354	Tensile Strength at Rupture	78,255
Silicon	·020	" " " Elastic Limit	33,605
Total Hardeners	·849	Percentage of Elongation	18·626
" in P. units	36·0	Proportional Ultimate Resilience	32·42

No. 392.—*In service from April,* 1871, *to April,* 1877; *six years. Was in south track on* 4° *curve,* 800 *feet east of M. P.,* 106 *from Pittsburg. Tonnage,* 32,957,247 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·231	Angle of Torsion	151°
Phosphorus	·087	Moment of Torsion	294
Manganese	·364	Tensile Strength at Rupture	69,090
Silicon	·047	" " " Elastic Limit	30,550
Total Hardeners	·729	Percentage of Elongation	29·548
" in P. units	26·0	Proportional Ultimate Resilience	37·24

No. 393.—*In service from July,* 1867, *to July,* 1873, *in north track at M. P.,* 115 *from Philadelphia; then from July,* 1873, *to April,* 1877, *in No.* 1, *south siding, Mifflin Yard. Total service, nine years, ten months. Tonnage,* 17,083,416 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·219	Angle of Torsion	217°
Phosphorus	·065	Moment of Torsion	285
Manganese	·272	Tensile Strength at Rupture	66,975
Silicon	·028	" " " Elastic Limit	28,200
Total Hardeners	·584	Percentage of Elongation	54·944
" in P. units	20·6	Proportional Ultimate Resilience	49·63

No. 394.—*In service from April,* 1871, *to April,* 1877; *six years. Was in south track on* 2° *curve,* 2600 *feet west of M. P.,* 27 *from Pittsburg. Tonnage,* 25,043,350 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·286	Angle of Torsion	149°
Phosphorus	·083	Moment of Torsion	322
Manganese	·418	Tensile Strength at Rupture	75,670
Silicon	·023	" " " Elastic Limit	45,825
Total Hardeners	·810	Percentage of Elongation	28·857
" in P. units	27·3	Proportional Ultimate Resilience	41 65

No. 395.—*In service from September,* 1872, *to March,* 1877; *four years, seven months. Was in south track on* 4° *curve,* 1200 *feet west of M. P.,* 59 *from Pittsburg. Tonnage,* 24,606,889 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·353	Angle of Torsion	134°
Phosphorus	·103	Moment of Torsion	338
Manganese	·576	Tensile Strength at Rupture	79,430
Silicon	·059	" " " Elastic Limit	32,900
Total Hardeners	1·091	Percentage of Elongation	23·860
" in P. units	36·5	Proportional Ultimate Resilience	37·49

No. 396.—*In service from January,* 1874, *to January,* 1877; *three years. Was in Subdivision* 11, *Pittsburg Division; the records of which were destroyed by the riots. Tonnage,* 13,683,266 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·350	Angle of Torsion	105°
Phosphorus	·134	Moment of Torsion	342
Manganese	·626	Tensile Strength at Rupture	80,370
Silicon	·058	" " " Elastic Limit	36,425
Total Hardeners	1·168	Percentage of Elongation	15·237
" in P. units	40·5	Proportional Ultimate Resilience	29·06

No. 397.—*In service from July,* 1872, *to May,* 1877; *four years, seven months. Was in south track on tangent* 650 *feet west of M. P.,* 11 *from Pittsburg. Tonnage,* 21,935,613 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·365	Angle of Torsion	82°
Phosphorus	·130	Moment of Torsion	260
Manganese	·458	Tensile Strength at Rupture	61,100
Silicon	·020	" " " Elastic Limit	25,850
Total Hardeners	·973	Percentage of Elongation	9·545
" in P. units	35·3	Proportional Ultimate Resilience	16·86

No. 398.—*In service from January,* 1871, *to March,* 1877; *six years, two months. Was in north track on* 4° *curve,* 120 *feet west of M. P.,* 12 *from Pittsburg. Tonnage,* 27,296,043 *tons.*

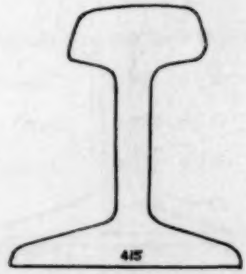
Chemical Analysis.		Physical Tests.	
Carbon	0·225	Angle of Torsion	130°
Phosphorus	·111	Moment of Torsion	282
Manganese	·318	Tensile Strength at Rupture	66,270
Silicon	·016	" " " Elastic Limit	27,025
Total Hardeners	·670	Percentage of Elongation	22·586
" in P. units	25·8	Proportional Ultimate Resilience	28·93

No. 413.—*In service from June,* 1867, *to October,* 1876; *nine years, four months. Was in single track on* 8° 40′ *curve, at west end of Schuylkill Bridge, Del. Ex. R. R. Tonnage,* 36,901,508 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·233	Angle of Torsion	175°
Phosphorus	·041	Moment of Torsion	280
Manganese	·208	Tensile Strength at Rupture	65,800
Silicon	·074	" " " Elastic Limit	28,435
Total Hardeners	·556	Percentage of Elongation	38·239
" in P. units	19·7	Proportional Ultimate Resilience	39·49

No. 414.—*In service from May* 1867, *to November,* 1876; *nine years, six months. Was in west bound freight track on tangent, east of 35th Street Bridge, West Philadelphia. Tonnage,* 34,839,538 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·309	Angle of Torsion	148°
Phosphorus	·058	Moment of Torsion	292
Manganese	·326	Tensile Strength at Rupture	68,620
Silicon	·030	" " " Elastic Limit	27,730
Total Hardeners	·723	Percentage of Elongation	28·514
" in P. units	24·1	Proportional Ultimate Resilience	35·86

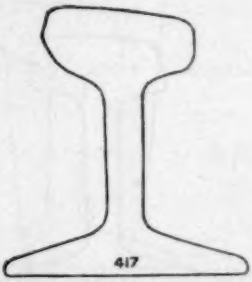


No. 415.—*In service from April,* 1867, *to July,* 1876; *nine years, three months. Was in south track, four years on* 2° *curve, and five years on tangent, near Marysville, Middle Division. Tonnage,* 48,037,879 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·336	Angle of Torsion	137°
Phosphorus	·079	Moment of Torsion	321
Manganese	·458	Tensile Strength at Rupture	75,435
Silicon	·061	" " " Elastic Limit	31,725
Total Hardeners	·934	Percentage of Elongation	24·833
" in P. units	31·3	Proportional Ultimate Resilience	36·75

No. 416.—*In service from June,* 1868, *to September,* 1876; *eight years, three months. Was in south track on tangent opposite Harrisburg Freight Warehouse. Tonnage,* 47,354,754 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·283	Angle of Torsion	127°
Phosphorus	·114	Moment of Torsion	289
Manganese	·334	Tensile Strength at Rupture	67,915
Silicon	·030	" " " Elastic Limit	28,200
Total Hardeners	·761	Percentage of Elongation	21·647
" in P. units	29·0	Proportional Ultimate Resilience	29·87



No. 417.—*In service from December,* 1867, *to July,* 1876; *nine years, six months. Was in north track on* 4½° *curve, at Jackstown Water Station, Middle Division. Tonnage,* 34,108,667 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·345	Angle of Torsion	124°
Phosphorus	·075	Moment of Torsion	312
Manganese	·426	Tensile Strength at Rupture	73,320
Silicon	·041	" " " Elastic Limit	30,080
Total Hardeners	·887	Percentage of Elongation	20·722
" in P. units	29·6	Proportional Ultimate Resilience	31·77

TABLE I.

Showing Tonnage, Location and Results of Chemical Analysis of Twenty-five Samples of Steel Rail.

Rail No.	Tonnage.	Location.	C.	Phos.	Man.	Si.	Total.	Tot. in Phos. Units.
415	48,037,879	2° C. and Tangent	0·336	0·079	0·458	0·061	0·934	31·3
416	47,354,754	Tangent.	0·283	0·114	0·334	0·030	0·761	29·0
390	47,332,411	2° Curve.	0·291	0·057	0·354	0·068	0·770	25·9
262	44,636,201	9° "	0·337	0·056	0·374	0·056	0·823	27·1
413	36,901,508	8⅞° "	0·233	0·041	0·208	0·074	0·556	19·7
414	34,839,538	Tangent.	0·309	0·058	0·326	0·030	0·723	24·1
417	34,108,667	4½° Curve.	0·345	0·075	0·426	0·041	0·887	29·6
392	32,957,247	4° Curve.	0·231	0·087	0·364	0·047	0·729	26·0
398	27,296,043	4° "	0·225	0·111	0·318	0·016	0·670	25·8
394	25,043,350	2° "	0·286	0·083	0·418	0·023	0·810	27·3
395	24,606,889	4° "	0·353	0·103	0·576	0·059	1·091	36·5
393	17,083,416	Tangent.	0·219	0·065	0·272	0·028	0·584	20·6
388	37,005,142	Tangent.	0·303	0·166	0·316	0·032	0·817	34·6
389	34,333,639	Curve.	0 343	0·127	0·670	0·036	1·176	39·3
391	30,873,173	4½° Curve.	0·294	0·181	0·354	0·020	0·849	36·0
397	21,935,613	Tangent.	0·365	0·130	0·458	0·020	0·973	35·3
277	16,600,728	"	0·573	0·075	0·853	0·182	1·688	52·9
396	13,683,266	Unknown.	0·350	0·134	0·626	0·058	1·168	40·5
83	10,027,131	9° Curve.	0·323	0·135	0·522	0·035	1·015	36·4
282	4,535,318	Tangent.	0 354	0·132	0·552	0·050	1·088	38·5
371	2,741,056	16° Curve.	0·386	0·127	0·380	0·053	0·946	35·8
372	2,741,056	17° "	0·416	0·155	0·460	0·034	1·065	40·3
373	2,741,056	20° "	0·300	0·138	0·412	0·024	0·874	33·2
347	5 Days' Service.	Unknown.	0·387	0·056	0·670	0·035	1·148	33·6
32	Broke 1st Train.	"	0·359	0·156	0·505	0·035	1·055	39·4

TABLE II.

Showing Tonnage, Location and Results of Physical Tests of Twenty-five Samples of Steel Rail.

Rail No.	Tonnage.	Location.	Angle of Torsion.	Moment of Torsion.	Tensile Strength.	Tensile Strength at Elastic Limit.	Elongation.	Ultimate Resilience.
415	48,037,879	2° C. and Tangent	137°	321	75,435	31,725	0·248	36·75
416	47,354,754	Tangent.	127°	289	67,915	28,200	0·216	29·87
390	47,332,411	2° Curve.	126°	302	70,970	32,900	0·213	31·95
262	44,636,201	9° "	No	tests	made	of this	rail.	
413	36,901,508	8⅓° "	175°	280	65,800	28,435	0·382	39·49
414	34,839,538	Tangent.	148°	292	68,620	27,730	0·285	35·86
417	34,108,667	4½° Curve.	124°	312	73,320	30,080	0·207	31·77
392	32,957,247	4° "	151°	294	69,090	30,550	0·295	37·24
398	27,296,043	4° "	130°	282	66,270	27,025	0·226	28·93
394	25,043,350	2° "	149°	322	75,670	45,825	0·288	41·65
395	24,606,889	4° "	134°	338	79,430	32,900	0·239	37·49
393	17,083,416	Tangent.	217°	285	66,975	28,200	0·549	49·63
388	37,005,142	"	120°	322	75,670	31,725	0·195	31·21
389	34,333,639	Curve.	121°	320	75,200	30,550	0·198	31·02
391	30,873,173	4½° Curve.	136°	333	78,255	33,605	0·186	32·42
397	21,935,613	Tangent.	82°	260	61,100	25,850	0·095	16·86
277	16,600,728	"	101°	433	101,755	43,005	0·142	36·81
396	13,683,266	Unknown.	105°	342	80,370	36,425	0·152	29·06
83	10,027,131	9° Curve.	106°	340	79,900	33,135	0·155	28·60
282	4,535,318	Tangent.	No	tests	made	of this	rail.	
371	2,741,056	16° Curve.	85°	342	80,370	47,000	0·102	24·68
372	2,741,056	17° "	102°	346	81,310	30,550	0·144	29·26
273	2,741,056	20° "	102°	281	66,035	25,850	0·144	23·06
347	5 Days' Service.	Unknown.	67°	306	71,910	30,550	0·065	16·65
32	Broke 1st Train.	"	111°	333	78,255	30,550	0·169	29·80

TABLE III.

Showing Tonnage, Location, Results of Chemical Analysis, and Physical Tests of Twenty-five Samples of Steel Rail.

Rail No.	Tonnage. Million Tons.	Location.	C.	Phos.	Man.	Si.	Total in Phos. Units.	Tensile Strength. 1000 lbs.	Elastic Limit. 1000 lbs.	Percent. of Elongation.	Ultimate Resilience.	
415	48	2° C. and Tangent	·336	·079	·458	·061	31·3	75	32	25	37	Did not Break or Crush in Service.
416	47	Tangent.	·283	·114	·334	·030	29·0	68	28	22	30	
390	47	2° Curve.	·291	·057	·354	·068	25·9	71	33	21	32	
262	45	9° "	·337	·056	·374	·056	27·1	No	tests	made		
413	37	8⅓° "	·233	·041	·208	·074	19·7	66	28	38	39	
414	35	Tangent.	·309	·058	·326	·030	24·1	69	28	28	36	
417	34	4½° Curve.	·345	·075	·426	·041	29·6	73	30	21	32	
392	33	4° "	·231	·087	·364	·047	26·0	69	30	29	37	
398	27	4° "	·225	·111	·318	·016	25·8	66	27	23	29	
394	25	2° "	·286	·083	·418	·023	27·3	75	46	29	42	
395	25	4° "	·353	·103	·576	·059	36·5	79	33	24	37	
393	17	Tangent.	·219	·065	·272	·028	20·6	67	28	55	50	
388	37	Tangent.	·303	·166	·316	·032	34·6	76	32	19	31	Broke or Crushed in Service.
389	34	Curve.	·343	·127	·670	·036	39·3	75	30	20	31	
391	31	4½° Curve.	·294	·181	.354	·020	36·0	78	34	19	32	
397	22	Tangent.	·365	·130	·458	·020	35·3	61	26	9	17	
277	17	"	·573	·075	·853	·182	52·9	101	48	14	37	
396	14	Unknown.	·350	·134	·626	·058	40·5	80	36	15	29	
88	10	9° Curve.	·328	·135	·522	·035	36·4	80	33	15	29	
282	5	Tangent.	·354	·132	·552	·050	38·5	No	tests	made		
371	3	16° Curve.	·386	·127	·380	·053	35·8	80	47	10	25	
372	3	17° "	·416	·155	·460	·034	40·3	81	30	14	20	
373	3	20° "	·300	·138	·412	·024	33·2	66	26	14	23	
347	0	Unknown.	·387	·056	·670	·035	33·6	72	30	6	17	
32	0	"	·359	·156	·505	·035	39·4	78	30	17	30	

Table III contains a condensed statement of the results of Chemical Analysis and Physical Tests, together with the tonnage and location of the 25 samples of rails analyzed. As has been previously mentioned, the rails analyzed have been divided into two groups. Those which *did not break or crush in service* have been placed first in Table III, and in the other tables of this report, and embrace the first 12 samples, down to and including No. 393. The remaining 13 rails either *crushed or broke in service.* To a study of this statement, attention is now directed.

But first a brief discussion as to the influence of the various substances affecting the quality of steel, viz., carbon, phosphorus, silicon and manganese, upon the metal, will perhaps be in order. And here, at the start, I should like to frankly confess that our knowledge of the influence of these substances upon each other, and upon steel, is far from being as complete as we could wish. How thoroughly this lack of knowledge is recognized, may be inferred from the fact that one of the important duties with which the U. S. Test Commission, organized some two years ago, was charged, was this very point of the influence of the various impurities which exist in iron and steel upon the metal and upon each other in the metal. In view of this lack of knowledge, we can only, as it seems to me, apply what is already known, and, at the same time, study the results which we ourselves have obtained, with a view of deriving from them, as far as possible, the information they are calculated to teach. What, then, is the influence, so far as we know, of phosphorus, silicon, carbon, and manganese, upon steel for rails? Phosphorus, even in very small quantities, hardens steel and makes it brittle, and, at the same time, seems to render it especially liable to fracture from percussion or blows. Silicon hardens steel and renders it brittle, but in less degree than phosphorus. Carbon hardens steel and makes it brittle, and, at the same time, up to certain limits, adds to its strength, but seems to diminish its ductility or percentage of elongation, almost directly in proportion to the increase in carbon and strength. Manganese hardens steel and renders it brittle, and adds to its strength, much like carbon, but in less degree, while, at the same time, it does not seem as rapidly as carbon to diminish the ductility, or percentage of elongation, proportional to the increase of manganese and strength.

Now it will be noticed that it is said of each of these four substances, phosphorus, silicon, carbon, and manganese, that they harden

steel and render it brittle. Phosphorus and silicon seem to harden steel without adding any other desirable qualities, except, perhaps, wear; while carbon and manganese seem likewise to have important influences upon the strength and ductility of the metal.

Leaving this point now for a moment, let us examine what qualities a steel rail needs to possess. A steel rail, as it seems to me, like every other piece of metal which is subject on the one hand to *strain*, and on the other, to *abrasion* or *wear*, has two things to avoid. On the one hand, it must not be so hard and brittle as to break under the strain or blows to which it is to be subjected; while on the other, it must not be so soft as to yield too rapidly to the abrasive action which it is to be called upon to withstand. If, now, this reasoning be correct, and if the influence which we have ascribed to the carbon, phosphorus, manganese, etc., be such as they actually possess, it would seem that we ought to find, by a study of the results of the chemical analyses—since the series analyzed embraces rails which have been broken or crushed in service, as well as those which have endured long and hard service—I say it would seem that we ought to find what amount of these hardeners or brittle-makers is so great that the rails have a tendency to break or crush in service; and this point being known, it is obvious that to get the most satisfactory wear, it is only necessary to have the rails as hard as they can be made with safety. In other words, if the limit of hardeners or brittle-makers is known, it is obviously good policy to make our rails approach this limit as closely as possible.[1]

A word now as to method of studying the hardeners. If we take any single hardener and follow it through the series, regarding it alone as to its influence on the steel, we will usually find that the principal thing that we will learn will be, that if any one of these hardeners is very high the rail broke in actual service. We will also learn that in the 12 rails which did not break or crush in service, the average of the carbon is 0·287 per cent., while in those which did break or crush in service it is 0·366 per cent.; while in the 11 rails

[1] In connection with this paragraph, upon the relation between the hardness and wearing quality of steel, I would like to call attention to a more full discussion of this question in a paper in these proceedings under the title, "Does the Wearing Power of Steel Rails increase with the Hardness of the Steel?" As will be seen there, the reasoning given above does not seem to be fully sustained by the facts in the case. (Oct. 12th, 1878.) [This paper will appear in our next number.—Ed.]

which withstood the highest tonnage, the average carbon is 0·30 per cent. Also, that in the 12 rails which did not break or crush in service, the average of the phosphorus is 0·077 per cent.; while in those rails which did break or crush in service, the average of the phosphorus is 0·132 per cent. And just here I may be permitted to call attention to what seems to me a very significant fact, viz., that in every case in which the phosphorus is above 0·12 per cent. the rail either broke or crushed in service. We will also learn by inspecting the analyses as to single elements, that the average manganese in the rails which did not crush or break is 0·369 per cent.; while the average in those which did crush or break is 0 521 per cent., and that the average silicon in the unbroken rails is 0·044 per cent., while in the broken or crushed rails it is 0·047 per cent.

But it seems to me that the true way to study the influence of the carbon, phosphorus, etc., upon steel is not to regard each one separately, but since all are known to render steel hard and brittle, to consider them *all as hardeners or brittle makers*, and study them in connection with each other. There are two ways in which this may be done.

(1.) We may simply add together the percentages of carbon, phosphorus, silicon and manganese, as they are given in the analysis, the sum obtained being regarded, of course, as a comparative measure of the hardness of the steel. Doing this, and we find that the average sum of these constituents in those rails which did not break or crush in service, amounts to 0·778 per cent.; while in those rails which did crush or break it is 1·030 per cent. It would, therefore, almost seem fair to conclude that we cannot with safety have the total sum of the carbon, phosphorus, silicon and manganese in our rails as high as one per cent.

(2.) There is another way of looking at these results of analysis which seems to lead to even better results than are obtained by simply adding together the percentages of the hardeners. It is a question which has been somewhat discussed among metallurgists, how much carbon, for example, would have the same influence in rendering a steel hard and brittle as 0·01 per cent. of phosphorus. Or again, how much silicon or manganese would have the same influence in this respect as 0 01 per cent. of phosphorus. I am not aware that any definite relations have ever been discovered between these substances in this respect. But it is, of course, evident if we wish to express

numerically the hardness of steel as derived from its chemical composition, we must estimate the influence of each of the hardeners in the same unit. Now I have assumed 0·01 per cent. of phosphorus as the unit of measurement, and have called this 0·01 per cent. a phosphorus unit. I have likewise assumed that 0·02 per cent. of silicon, 0·03 per cent of carbon, and 0.05 per cent. of manganese have each the same influence in rendering a steel hard and brittle as 0·01 per cent. of phosphorus. In any analysis of steel, therefore, the phosphorus units are found by adding together the phosphorus, $\frac{1}{2}$ the silicon, $\frac{1}{3}$ the carbon, and $\frac{1}{5}$ the manganese, expressed in hundredths per cent. Applying these data to the chemical analyses of the series and we find that the average sum of the hardeners—expressed in phosphorus units—in the rails which did not break or crush in service is 27, while the average sum of those which did break or crush is 38. Examining now Table III, a little in detail and we find that with one exception, No. 395, the total sum of the phosphorus units in the good rails in no case exceeds 31, while most of them are 29 or below; while, when we examine those rails which either crushed or broke in service, in no case is the total sum of the phosphorus units less than 33. It would almost seem fair to conclude, therefore, that, measured in phosphorus units, in the manner described, we cannot have rails whose total sum of hardeners in phosphorus units is over 31 or 32. Now, as has already been stated, I think no one will affirm that for successful wear the hardeners should be lower than is consistent with safety.[1] But in the rails which have not broken or crushed in service we find only one, No. 395, whose sum of hardeners is over 31. Therefore, measured in phosphorus units, it seems clear that the sum of the hardeners in rails for use on Pennsylvania Railroad should not vary far from 30. The "total hardeners" and "phosphorus units" given in the pages of this report, which contain the diagrams of the rails analyzed, are obtained in the manner described above.

And now, how shall the hardeners be distributed? It has already been mentioned that in every case where the phosphorus is above 0·12 per cent., the rail either crushed or broke in service. Examining the phosphorus in rails which did not crush or break in service, we find that in no case is it above 0·11½ per cent., while in almost every case it is below 0·09 per cent. Remembering now that phos-

[1] See Note to page 383.

phorus makes steel brittle and especially liable to fracture from blows, and it would, perhaps, seem fair to place the limit of phosphorus at 0·10 per cent. As to silicon, the less in the rail the better. Nevertheless, as by the Bessemer process it is impossible to make rails entirely free from silicon, a small limit must be allowed for silicon. As the process is ordinarily worked, perhaps 0·04 per cent. will not be too high a limit.

The ability of rail-manufacturers to control the amount of carbon and manganese in the steel, requires a little broader limits for these two elements. If, now, we place the carbon at from 0·25 per cent. to 0·35 per cent., and the manganese at from 0·30 per cent. to 0·40 per cent., and are able to obtain rails on this formula, which are not injured or spoiled during the manufacture, I think we will get rails which will be entirely safe, and, at the same time, give satisfactory wear. The sum of the hardeners, measured in phosphorus units, for the limits of the formula, amounts to 26 for the lower limits of carbon and manganese, and to 32 for the higher. In view of the tendency to higher carbon which has seemed to prevail for a few years past in rail manufacture, it may appear that the carbon limits given above are low. But that this is correct will, I think, be evident from the considerations which follow. Of course if we could make a formula just as we would like, it would, perhaps, be entirely scientific to take the average of the carbon, phosphorus, manganese, etc., in the best rails as the standard for this formula. Doing this for the rails which did not crush or break in service and we have, carbon, 0·287 per cent.; phosphorus, 0·077 per cent.; manganese, 0·369 per cent.; silicon, 0·044 per cent.; and the same for the 11 rails which withstood the highest tonnage, and we have, carbon, 0·30 per cent.; phosphorus, 0·091 per cent.; manganese, 0·38 per cent.; silicon, 0·045 per cent. But in view of the difficulty of obtaining low phosphorus in this country, we have put it as high perhaps as it should be, viz.: 0·10 per cent. If, now, we make high carbon, we must diminish the manganese, or our total hardeners will be too high. That carbon should not be increased at the expense of manganese will, I think, be evident from an examination of the formula given just above, derived from the average composition of the best rails, as well as the separate analyses in Table III.

Both the formulas given above show the carbon to be lower than the manganese, and both are within the limits which we have given for

carbon and manganese, viz.: 0·25 per cent. to 0·35 per cent. for carbon and 0·30 per cent. to 0·40 per cent. for manganese. Again, in the separate analyses of the rails which did not crush or break in service, in only one case, No. 413, is the carbon higher than the manganese. Moreover, if the influence which we have ascribed to manganese, viz., that it increases strength and hardness of steel without diminishing elongation as much as carbon would do, be correct, the rails which we get on a formula in which manganese is higher than carbon, will be less liable to break or crush in service, and at the same time will, perhaps, give as satisfactory wear as if the carbon had been increased and the manganese diminished.

II.—Physical Tests and Inspection.

The question now arises what physical tests and inspection shall the Pennsylvania Railroad Company prescribe to the rail manufacturers to enable it to secure rails uniform in quality?

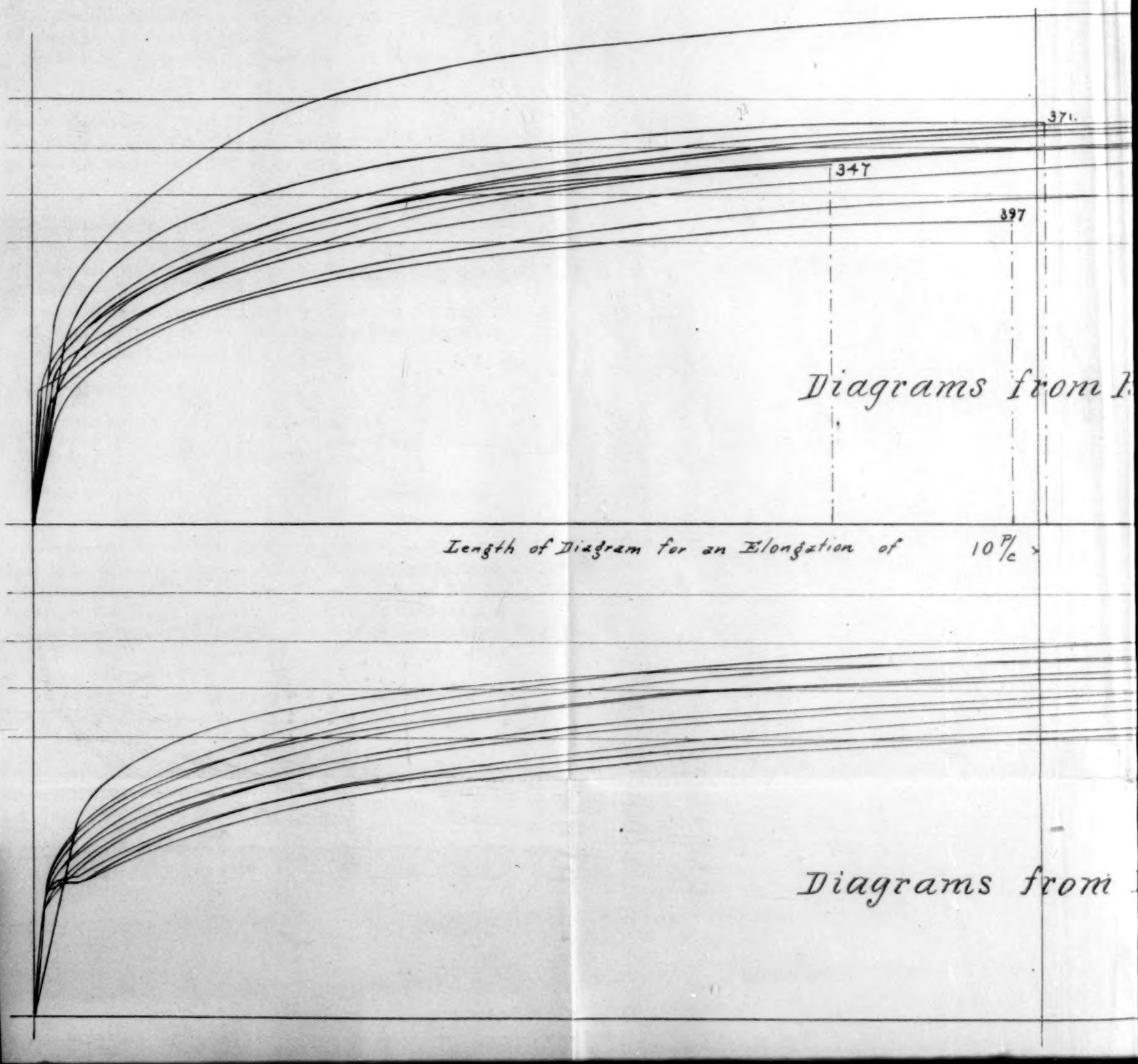
The inspection which is at present employed seems to be amply sufficient to enable us to discard rails whose defects are evident to the eye. The question as to physical tests is not so easily answered. Nevertheless, three methods of applying physical tests suggest themselves.

(1.) The bending test now it use. It seems to me fatal to this test as at present conducted that the test bar, ¾ inch square by 12 inches long, is hammered out from a piece of the rail. It is conceded, I think, that in proper hands a piece of steel is changed by hammering. We are, therefore, not testing the steel in the rails, but a different quality of steel. If the present bending test is to be continued, I would suggest that the test bar be cut from the rail head, instead of hammered from it.

(2.) The Drop Test. This test was in use for some time on the road to determine the quality and uniformity of the rails purchased. With regard to this test it may be said that unless the foundations are very solid, much of the force of the blow is lost; so that a rail tested under a rickety drop might stand the prescribed test, which, under a firm one would yield. It would seem, therefore, that the drop test, without extreme care and inspection on the part of the railroad company to hold the rail manufacturers up to specifications, would give erroneous results. It is due to this reason, as I understand, that the drop test was abandoned.

(3.) Still another method of testing our rails suggests itself, and that is to ask the rail manufactures to provide themselves with and use the same kind of machine upon which the physical tests of the series of rails analyzed have been made, viz.: Thurston's Torsional Testing Machine. That this would be the most valuable method of securing uniformity in the rails furnished us, will be evident, it seems to me, from a study of the physical tests in Table III. It should be stated here that of all the data in regard to the physical qualities of metal furnished by this machine, which data are given in full for record, in connection with the analyses, in the preceding pages, and are tabulated in Table II; we have selected out two, viz.: Tensile Strength and Percentage of Elongation, as best expressing the value of the steel with our present knowledge of the subject. It should also be stated that the tensile strength given in this report is $\frac{94}{100}$ of that obtained by the formula for determining the tensile strength which accompanies the machine, this being found by comparative tensile and torsion tests to most nearly express the tensile strength of this grade of steel.

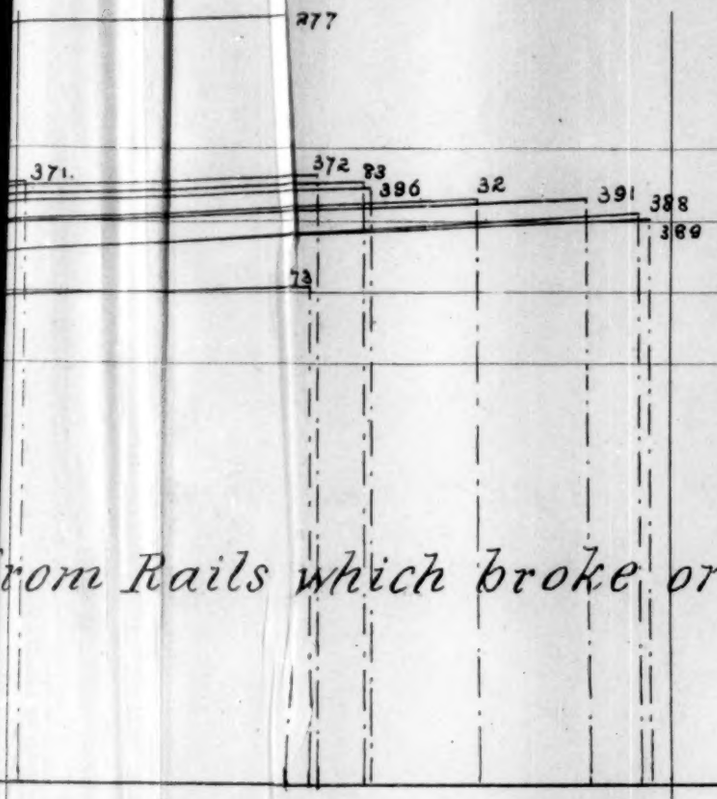
Turning now our attention to Table III to the rails which crushed or broke in service, and noting that in the case of No. 397 the test is not very reliable on account of inability to secure a full size test piece from the rail sent for analysis, and we find that in every case except two, No. 373 and 347, the tensile strength of these rails is 75,000 pounds or above per square inch, while the percentage of elongation is 20 per cent. or below. Turning, now, to the rails which did not break or crush in service and we find, with the single exception of No. 395, the tensile strength is between 65,000 pounds and 75,000 pounds per square inch, while the percentage of elongation is 21 per cent., or above. If, therefore, we had had specifications that our rails should have a tensile strength above 65,000 pounds per square inch, and a percentage of elongation above 20 per cent., as determined by the machine referred to, a simple inspection of Table III. shows absolutely that we would have been able to reject every rail in this series which has crushed or broken in service. The same facts, and especially the defective elongation of the rails which broke or crushed in service is made evident to the eye by an inspection of the accompanying diagrams of tests of the rails analyzed and described in this report, and from which the physical tests given in this report were computed.


371.
347
397
Diagrams from
Length of Diagram for an Elongation of 10 P/c
Diagrams from

CAL COMPOSITION AND PHYSICAL PROPERTIES OF STEEL RAILS.

By C. B. DUDLEY, Ph. D., Chemist, Penn. R. R. Co.

Altoona, Pa., Nov., 1877.



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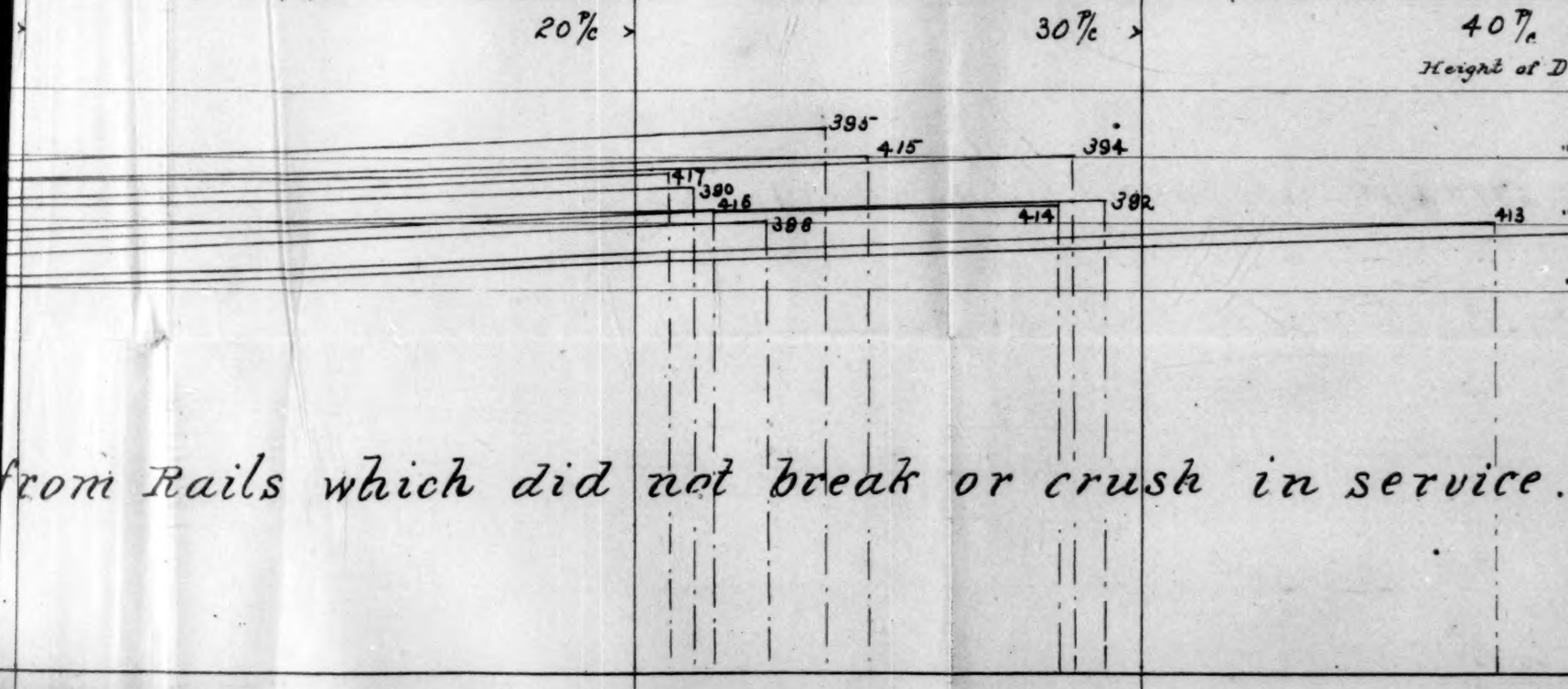
from Rails which broke or crushed in service.



from Rails which did not break or crush in service.

of Diagram for Tensile Strength of 84,600. lbs.

"	"	"	"	"	75,200.
"	"	"	"	"	65,800.
"	"	"	"	"	56,400.

In these diagrams, Tensile Strength is
uted from the height of the curve a-
the datum-line, while Elongation or
lity is computed from the length of
iagram measured from the origin.

40 P/c

50 P/c

ight of Diagram for Tensile Strength of 84,600. lbs.

	"	"	"	"	75,200. "
413	"	"	"	"	65,800. " 393
	"	"	"	"	56,400. "

vice.

In view of the discussion and considerations given above, it seems fair to conclude:—

(1.) That with our present metallurgical methods high phosphorus in rails is inconsistent with safety.

(2.) That silicon should be as low as is consistent with the successful working of the Bessemer process.

(3.) That the best range for carbon is from 0·25 per cent. to 0·35 per cent.

(4.) That the best range for manganese, all things considered, is from 0·30 per cent. to 0·40 per cent.

(5.) That the total sum of the hardeners, expressed in phosphorus units in the manner described, should not be above 31 or 32, nor below 25.

(6.) That the tensile strength of rails for use on the Pennsylvania Railroad, determined in the manner described in this report, should be above 65,000 pounds per square inch, and that the percentage of elongation determined in the same manner should be above 20 per cent.

I would, therefore, respectfully recommend that the following formula be prescribed for the chemical composition of rails for the use of the Pennsylvania Railroad, viz.:

Phosphorus, not above	0·10 per cent.
Silicon, " "	0.04 "
Carbon, between 0·25 and 0·35 per cent., with an aim at	0·30 "
Manganese, between 0·30 and 0.40 per cent. with an aim at	0·35 "
Sulphur and Copper, ...	No specifications.
All other impurities, not more than traces.	

Also, that the rail manufacturers be requested to procure one of Prof. R. H. Thurston's Torsional Testing Machines, and to furnish test pieces from each "blow," ready for testing, to our Rail Inspector, or other person authorized to attend to that work, who shall test the same on this machine, and that we shall be at liberty to reject all "blows" which do not conform to the physical tests, shown to be essential in the body of this report.

And I would also recommend that the rail manufacturers be informed that we feel ourselves at liberty, at any time, to make chem-

ical analyses of the rails furnished us, and if at any time the rails are found to differ from the above specifications, it will be regarded as a breach of contract and a proper subject for adjudication.

Very truly yours,

CHAS. B. DUDLEY,

ALTOONA, *Nov.* 13*th*, 1877. *Chemist Penna. R. R. Co.*

EFFECT OF THE MOTION OF THE AIR WITHIN AN AUDITORIUM UPON ITS ACOUSTIC QUALITIES.

By W. W. JACQUES,

Fellow in Physics of the Johns Hopkins University.

It is the purpose of this paper to give an account of some experiments made for the purpose of determining the effects of the currents of air within an auditorium, upon its acoustic qualities. These experiments are in three series. The first being a laboratory investigation into the effects of currents of air upon a ray of sound. The second and third, studies, by different methods, of the effects of the currents of air in a lecture hall and a theatre, upon the waves of sound.

Since the air of a hall is the medium by which sound is conveyed from the speaker or singer to the hearer, it would certainly seem of fundamental importance that this air should be in the condition best suited to the propagation of sound. Experiments made by the author, in a considerable number of halls, show that the atmosphere is almost invariably disturbed by currents of air of varying density crossing the room in all directions. These currents have been traced out with thistle balls and their velocity measured with the anemometer. The estimates of density have been made from the velocity of motion. Now the experiments of Prof. Tyndall have shown that currents of air of varying density form one of the chief obstacles to the propagation of sound-waves. The author, in repeating these experiments in a somewhat modified form, found that such currents of air not only decrease the intensity of a sound-wave, as Prof. Tyndall has shown, but that they actually modify its form, and so give rise to great indistinctness. The experiments were made as follows: At *A* was placed a source of sound,

$$A + - + - + - + - + E,$$

being in some cases an organ-pipe, in others, a man who spoke in a clear and distinct voice, and in others, various musical instruments, on which simple combinations of notes were played. Just below the points, + +, etc., were placed substances heated to such temperatures as to give rise to currents of air corresponding in density to those found in an auditorium. At *E* was placed the ear, which, though it be not so reliable an instrument as the singing flame of Prof. Tyndall for estimating intensities of sound, is, of course, the best instrument imaginable for determining their qualities. The results of the experiments were as follows: The ear being placed at *E*, and a small lead organ-pipe, blown with a constant pressure of air, at *A*, the heated bodies were placed under + +, etc. A very decided decrease in the intensity of sound was noticed; but it was also noticed that the previously clear note lost its *distinctness*. The pipe was removed, and a man was placed at *A*, who spoke in clear and well-defined tones. The effect was not only to decrease the intensity of his voice, but to make it slightly confused and indistinct, as if each syllable were repeated several times in very close succession. When a flute was substituted for the voice, the effect was the same. The effect on a violin seemed to be considerably less. With a drum, no effect whatever was observed. The effect seemed to be most marked on the man's voice, or a musical instrument in which the overtones were comparatively small. The explanation of this is very simple. The original ray of sound, striking upon the first current of air, is partially reflected and partially transmitted. The loss of the reflected portion causes a decrease in the intensity of sound. The transmitted portion, striking upon a second current, is likewise divided, and its transmitted portion continues to be so divided as many times as there are variations in the density of the air. Its reflected portion, as well as that of all the succeeding reflections, instead of being wholly lost, is interrupted in its backward course by the first current of air, and reflected along the path of the primary wave, but following it at an interval of time, depending upon the thickness of the current of air. Each reflection being thus again and again reflected and divided, we have, following close upon the primary wave, a multitude of secondary waves, which, falling upon the ear, greatly mask the distinctness of the original sound. Currents of air of varying density then cause, first, a *decrease in intensity* of sound, and secondly, an *indistinctness*, or confusion of the sound.

That currents of air, which we have thus studied in the laboratory, act in the same way in an auditorium, may be shown by the following experiment, in which the sound-waves may be actually traced out in space, and their confusion, consequent upon the introduction of currents of air, likewise shown.

Near the middle of a lecture hall, 92 feet long and 65 feet wide (the hall of the Massachusetts Institute of Technology, in Boston), a heavy plank, six feet wide and twelve feet long, was set on one end and firmly fixed. Eight feet from its middle point, on one side, was placed a B 4 stopped lead organ-pipe, which was so connected with a gasometer as to be blown with a constant pressure of air.

On the other side of the plank, and within the sound shadow, a system of coördinates, in a plane parallel with the floor, was established, by means of light wooden rods, which ran parallel and perpendicular to the board, and their length divided into centimetres.

Now it has been shown by the author (*Prac. Am. Acad. Arts and Sciences*, May 10th, 1876), that rays of sound diverging from such a source, and being diffracted around the edges of the board, will, when they meet each other, after having passed over paths differing by a half wave-length, neutralize each other and produce comparative silence. By moving a B 4 resonator, connected by means of a rubber tube with the ear, along these coördinates, the points of interference are easily detected and are found to be situated as predicted by formulæ similar to those used in the diffraction of light. In fact, the cases are entirely analogous.

We have here, then, a means of mapping out the positions of the sound-waves in space, and can say that at one point there is silence, because two sound-waves have met crest upon the trough, and neutralized; at another the sound is loud because two waves have met, crest and crest, and trough and trough, and have doubled. All this is true so long as the air of the hall is at rest, and these experiments have been made with doors, windows and registers carefully closed.

Everything being in this condition and the sound-waves having been mapped out, the doors and windows were thrown open to the winter's air, and the registers were opened to admit as many streams of air heated to nearly 100° C. What is the effect? Currents are rushing about the hall in every direction (we have the conditions of the laboratory experiment), the waves of sound are superimposed by numberless reflections whose points of condensation do not coincide,

and the phenomena of diffraction instantly disappears. This experiment was many times repeated, and always with the same results.

It is evident, then, that in order to procure the proper propagation of sound, we must do away with these air-currents. It must be remembered, however, that when large numbers of persons are crowded into halls, the air within is usually subjected to very considerable disturbances in order to obtain even indifferent ventilation. How, then, shall we obtain the desired ventilation and at the same time prevent the formation of currents of air?

The solution of this problem seems to me to be given in the third series of experiments, which were carried out in the "Baltimore Academy of Music," designed by Mr. J. Crawford Neilson, architect, of that city.

The ventilation of this house is so arranged as to prevent largely the formation of air-currents of unequal density. According to a survey, made with thistle balls and the anemometer, of the space contained within the walls of this theatre, the movement of the air is as follows:

The whole supply of fresh air is admitted at the back of the stage, is there warmed, then crosses the stage horizontally, passes through the proscenium and then, somewhat diagonally towards the roof, across the auditorium in one grand volume and with gentle motion so as to almost entirely prevent the formation of minor air-currents. It is exhausted partially by an outlet in the roof and partly by numerous registers in the ceilings of the galleries. From this central outlet and from the large flues of the registers the air passes into the ventilating-tower over the great chandelier, which supplies, in its heat, a part of the motive power of the circulation. It is further expelled from the tower by means of large valves so contrived that, while they offer no obstacle to the *egress of air*, they completely *deny it entrance*. The amount of air so passed through the house is, as determined by a series of experiments, about fifteen thousand feet per minute. This amount, sufficient to ventilate the house, is just what seems to be required to impress the proper movement on its atmosphere. That it is amply sufficient for ventilation is shown by the fact that the thermometers of the upper circle do not vary perceptibly from those of the orchestra circle.

The seating capacity of the house is about sixteen hundred persons. The acoustics are, if we may judge from the testimony of a

large number of singers and speakers, as well as from our own observation, among the best.

The weakest voice is audible to every seat in the house, sounds such as a sigh, a kiss, or even the simulated breathing of the somnambulist may be heard in the most distant parts, and all effects in music are exactly rendered. All singers and speakers agree in describing the facility with which the voice is used on this stage.

It now remains to show that the universally acknowledged acoustics of this house are largely due to the *condition of the air*, and not to the arrangement and material of the walls, together with other well-known causes of success or defect. For this purpose, persons have been repeatedly stationed at different parts of the house during a performance, without being informed of the nature of the experiments to be carried out. They have simply been asked to note, at intervals during the evening, the comparative ease with which they could hear the performers. At various intervals during the evening, the valves which control the ventilation were reversed, so as to entirely interfere with the unbroken condition of the air, and give rise to currents of circulation. Almost invariably the testimony of the hearers would be, that at times corresponding to the interruption of the ventilation, the "sound was dead," was "confused and indistinct," and it would be observed that people all over the house would make an effort to listen. As an example of these experiments, the following is copied from the author's notes, for the evening of January 24th, 1878.

There was a concert, consisting of orchestral music and solos, held in the house. At eight o'clock, observers, A, B, C and D, were stationed respectively in the orchestra, right and left wings of the balcony, and on the bridge that spans the stage above the level of the highest proscenium boxes. They were entirely ignorant of the nature of the experiment, and were simply requested to note the times of good and bad hearing.

At half-past eight o'clock the valves were reversed, and remained so till nine, when they were again set aright; after the performance, the following testimony was given by the different observers:

A.—Orchestra—to 9.15, very indistinct; 9.15 to 10, much better.

B.—Right Balcony—8.45 to 9.15, sound was dead; 9.15 to 10, decidedly better.

C.—Left Balcony—8.00 to 8.40, good; 8.40 to 9.15 confused; 9.15 to 10, good.

D.—*Over* Stage—8.00 to 8.30, good; 8.30 to 9.00, strong draught, hearing better; 9.10, draught disappeared.

An examination of this table shows that the observers in the auditorium found a period of half an hour's duration when the sound was not so plain as it had been before, or was after. This time was of the same length, but from 10 to 15 minutes later than the period of interruption of the ventilation; but some time is, of course, necessary for the air-currents to form, or, being formed, for them to be destroyed.

The observer, D, over the stage, however, found the hearing *better* during the half hour of interruption, and this is exactly what would be expected; for the interruption of the current of air through the auditorium, causes it instead to rise directly over the stage into the large space in which hangs the scenery, and thence out of the building.

During Neilson's performance of "Rosalind," observers A and B were stationed in the first and C and D in the second balcony from 8.00 to 10.00 P. M. At 8.50 o'clock the ventilators were closed and the lobby doors, together with those leading from the lobby to the street, were thrown open.

Thistle balls let loose from the balconies showed currents of air coming in at the doors and crossing the auditorium towards the stage. At 9.20 the doors were closed and ventilating-valves set aright. The testimony of the observers was as follows:

A.—First Balcony—8.00 to nearly 9.00, good; for about half an hour, bad; afterwards, much better.

B.—First Balcony—8.00 to 9.00, good; 9.00 to 9.30, bad; 9.30 to 10.00, good; strong current of air felt from the door a little before 9.00.

C.—Second Balcony—8.00 to 8.50, good; 8.50 to 9.20, bad; 9.20 to 10.00, good.

D.—Second Balcony—8.00 to about 9.00, good; 9.00 to 9.20, bad; 9.20 to 10.00, good.

In the foregoing paper we have studied the effects of air-currents upon the acoustic qualities of an auditorium. That this is only one of the factors on which success depends the author knows full well, and experiments are now in progress upon some of the other causes which modify the acoustic properties of churches, theatres and halls.

These, however, have been in part studied before, while the above researches are believed to be entirely new.

ON FURTHER APPLICATIONS OF THE FLOW OF SOLIDS.

By M. Henri Tresca, President of the Societé des Ingénieurs Civiles, Paris.

(Concluded from Vol. lxxvi, page 334.)

An entirely different effect is produced when a medal is struck. The blank piece having been placed in the matrix, the portions which are not to be raised in relief by the action of the press are reduced in thickness, for the benefit of the neighboring portions which are raised; the metal literally flowing, in radial directions, from the hollows to the reliefs by which they are surrounded.

If the medal has only an engraved face, it may be made up of several blanks of equal thickness superposed. The same mode of distribution of the molecules takes place, and is manifested by successive imprinting at each face, in which the final relief is more or less obliterated.

It is so clearly a manifestation of flow that takes place under these conditions, that if the bottom of the matrix be hollowed out at the centre, then, the material which converges from the circumference exciting a pressure towards the centre, the central portion of the blank is driven towards the orifice, where it forms a very regularly shaped boss; admitting of the transformation of a relief executed on a plane, into a similar relief on a surface which has become very convex or very concave, according as the design pertains to the upper or the lower face of the blank.

To an analagous cause, the presence of scars sometimes observed on medals highly relieved, is to be attributed; these scars being produced simply by the junction, during the latter strokes, of the edges of the bosses which are formed by the earlier strokes.

When the medal is relieved on both faces, if it be made up of several plates superposed, it is interesting to remark the successive developments and effacements of the images on both sides of the plates; mingling and merging in each other in a singular manner.

Rules cannot yet be formulated for the best forms of the grooves of rolls; but it may be accepted that they should be shaped in such a manner as to utilize as far as possible the natural flow of the metal in the direction of the pressures applied to it.

It has been shown that when a bar is to be drawn out, it is best to prevent any enlargement of it laterally, and to facilitate the longigitudinal flow; the die should, therefore, be carefully gauged, short, and opened out in the direction of the length.

It has been seen, also, that in stamping a disk, it may be useful to make use of centripetal compression. Each mode of action has thus its own mode of deformation of which it is necessary to know how to take advantage. The following is a very remarkable instance: Given a disk of lead 4 inches in diameter and $\frac{1}{8}$ inch thick; if it be pressed, in the stamping machine, for a diameter of $2\frac{1}{2}$ inches at the centre, the thinning of this central portion is only effected by the flow of the material outwards; and this flow is exactly symmetrical, when the centering is perfect. The exterior border is developed in the form of a tulip. By such means, without the employment of a matrix, geometrical forms of a perfectly definite character may be produced, which may be useful in some cases.

This general disposition of material had been long since observed by MM. Piabert and Morin, in the course of their experiments in drawing out blocks of clay. Around the orifice of entry the clay was thrown out in the form of acanthus leaves, and the same development is to be observed in the displacements which take place when projectiles are discharged against armor plates. The metal displaced by the projectile is driven forward in flakes or strata more or less involved and dislocated, which have, nevertheless, a striking family likeness to the dispositions previously noticed.

The geometrical condition of the development in tulip-form of the plate of lead, may be very simply explained. The border of the plate, which makes an effort to retain unaltered its diameter and its thickness, continues to be attached to the central portion, the gradual crushing of which throws out rings which are successively thinner and thinner. These rings have, therefore, at each instant, a given thickness, and by their succession they necessarily form a surface of revolution, which is accurately calculable, on the hypothesis, which is perfectly justifiable, that the volume is constant.

The conditions of such development may be modified by the employment of casings of various forms, but attention will be confined to the case of a concentric casing so disposed as to prevent any increase of diameter.

Eight disks of lead $1\frac{1}{2}$ inches in diameter have been placed in a cylinder, a piston of 1·20 inches in diameter is placed upon the pile

formed by these plates. Since the material can only escape from the compressive action by the annular space comprised between the piston and the cylinder, it ultimately assumes the form of a sort of tumbler, of which the height is extended to the length of the piston, even beyond the length of the cylinder. The thickness of the tumbler, 0·15 inch, would have been more regular if but one disk of lead, or of tin, had been employed. But the mode of distribution of the layers in the thickness of the tumbler is in itself a useful subject for consideration. The uppermost plate has been developed, almost in one piece, to the upper edge of the tumbler, being connected by a continuous supplementary part, which becomes gradually thinner until it reaches the foot of the tumbler. The other plates are also developed, in a parallel direction, supported by the sides of the cylinder, for a length which may be submitted to the same kind of calculation as that of the plates of the concentric jets. It is the same mode of deformation applied, in the present case, to an annular jet; and the complete analogy between the formulæ which give expression to their relations is not one of the least remarkable facts in these transformations.

This method has for several years been adopted in industrial operations, under conditions of precision which are truly astonishing, in which a vertical and cylindrical jet, 12 inches high, is manufactured from a sheet of tin perfectly smooth and of uniform thickness. In the finest specimens of that size, the ends of the tube, which are pared after having been struck, do not show any irregularity exceeding $\frac{1}{12}$ inch in height, even though the cylindrical envelope has been suppressed for the whole height. The substance driven out in the form of a ring, the thickness of which is measured by the difference between the radius of the punch and that of the matrix, is naturally disposed to form a thin cylinder, the several elements of which slide with equal facility upon the perfectly polished surface of the punch.

A thousand examples of similar surprises may be found in industrial processes; but this instance, amongst them all, definitively sanctions the expression by which the author believes he is authorized to designate the results of his researches. The flow of solids is now recognized in science; much more will it be accepted by the members, who are witnesses every day of the processes which are based upon it, as the true expression of the best ascertained facts.

Planing.—Of the various operations which have been described above, that of punching is the only one which has had for its object the dividing of a solid body, and forming two entirely separate parts —the burr and the punched block. The block is augmented by compression of a portion of the matter which constituted the cylinder which would have been simply pushed out by the punch, supposing that the cylinder could have slipped out without giving rise to other phenomena. The burr is reduced by the same amount.

Cutting or shearing does not really take place until the moment when the burr, in consequence of lateral flow, has been reduced to its final height. It has been proved that from this moment the resistance opposed to shearing is actually proportional to the area of the zone of shearing. The coefficient of resistance applicable to this separation is no other than the coefficient of resistance of fluidity; or what amounts to the same thing, the coefficient of resistance to rupture; so that we are now put in possession of a certain formula, applicable equally to circular shearing by the action of the punch, and to rectilinear shearing by the shear blade or by the turning tool.

In each case one of the parts of the piece slides upon the other part, producing at the two sides in contact a drawing out of the successive layers, which are bent over in the direction of the length of the shorn surface, in thin shreds, like those produced by the punch. The separation only really takes place at the moment when these shreds are drawn to their extreme limit of tenuity.

This characteristic of the separated surfaces is met with in planing, although the principal circumstances may here be entirely different; not less remarkable, however.

The principal difference consists in this, that the chief compression takes place not in the solid mass as before, but in the cutting which is detached by the tool, which, as it forms the exterior portion, opposes to the flow the least resistance. If the cutting be compared with the space which it occupied in the block before separation, it is easily observed that it is at the same time considerably shortened, and that, consequently, its thickness has been augmented in the inverse ratio of the shortening.

This leading fact in planing is very well exemplified in the turning from the wheel-tyre of a locomotive, comprising a cutting from the rivets. These are represented as of an elliptical section, 1½ inches

by $\frac{4}{10}$ inches, showing that the reduction in length affected by the action of planing was in the ratio of 10 to 28, or 0·36. This coefficient of reduction is still much greater than it is in many other circumstances; for the thinnest cuttings, the coefficient is occasionally as low as 0·10.

In another instance, a cutting planed off transversely from a double-headed rail, the height has not been altered, but the width has been reduced nearly in the same proportion as in the first example.

Another characteristic of cuttings produced by planing is that the surface of the cutting which rises from contact with the cutting-tool is always smooth, and is developed geometrically. That surface, in fact, is moulded on the tool during the process of deformation, and slides upon it in such a manner as to roll itself up in the form of a cone or of a cylinder. At this moment, above all others, the plasticity of the metal is brought into play; and if the original form of the cutting should interpose too serious obstacles to this development, it tears or splits according to the direction of the generating surfaces of contact, still responding to the geometrical condition first referred to. It is well to avoid such rents as much as possible, for evidently they cannot be produced without the expenditure of additional power. Such loss of power must take place, especially where it is required to reduce a curved surface at one cut, of great breadth. An example of such fissures is shown on about the third of the width of another cutting from a tyre; but those of the opposite edge are attributable really to a greater reduction of the length of the thinner edge in the process of planing

The other face of the cuttings is always rugged and wrinkled with fissures or with transverse ridges, of every variable aspect, according as the metal is more ductile and the cutting is thicker. For the greater thicknesses both iron and steel present on that surface a multitude of inclined ridges partly covering one another; and of which the incline is still better defined where complete separation has been produced.

These scales have been drawn just as they appear under the microscope, on a cutting of Bessemer steel. Nothing can show better than their general inclination the sliding that may be produced in planing, in consequence of the compression which is produced in front of the tool before the cutting is completely detached from the block.

In the greater number of cases the turning when long enough winds up into a helicoidal form, as may be seen on the cutting, of which the rugged face has just been shown.

The inclination of the spirals depends upon that of the cutting edge of the tool, and their diameter upon the thickness of the cutting; the diameter diminishing with the percentage of reduction. It is thus that, in turning in the lathe a piece which is very slightly eccentric, the result is a number of parts of which the diameters are alternately greater and less. The demonstration afforded by this single specimen is quite complete.

Without seeking to draw any conclusions from the study of these deformations with respect to the best form of tools for each of them, it follows clearly from the foregoing discussion that the work required for any cutting action whatever is expended in friction and in deformation by compression. The work of friction should augment with the number of cuts, and as the shortening is greater for the finer cuts, the molecular work expended should be greater. It follows, therefore, that it is most advantageous to make deep cuts, but of course this mode of action demands more powerful tools and better foundations. It is in this direction, it appears, that the most recent progress in the manufacture of tools has been effected.

The different modes of cutting, rectilinear or circular, are applicable chiefly to flat surfaces and to cylindrical surfaces.

Flat surfaces are cut in the planing machine or in the lathe, and under most circumstances the two kinds of cuttings are almost identical in appearance—that of a cylinder formed of spirals more or less close, sometimes even in juxtaposition; but for this combination, it is necessary that the two edges of the cutting should have been equally reduced, that is, that they should be of the same thickness. If it were otherwise, the spirals would become conical; and such of these as appear to be most characteristic will now be described.

The cutting obtained in mortising, by means of a straight tool, is absolutely cylindrical.

When the tool cuts out, in this manner, a rectangular groove, the material is compressed without any lateral deviation. If the cutting is of great thickness, it is triangular, and the smooth surface is formed by the combination of the three faces at which the separation takes place, the direction in which crumpling takes place being the same as

in all ordinary cuttings. The triangular form is the result of the compression being greater towards the middle line.

To aid in forming an opinion on this point, two blocks were placed side by side, which were planed at the same time, in the line of junction of the pieces. Two distinct horns were formed, which parted symmetrically from one another; each half-cutting following the law of shortening by which it was bound to assume a form concave towards the side which was held by its attachment to the block.

Having made a similar experiment in lead, the parallel and equidistant lines that were drawn upon the block before it was cut could be traced on the cutting, and they afforded the means of measuring exactly the average percentage of reduction, and the mode of contortion of these transverse lines, which assumed successively the same inclinations as they lay one upon another at intervals, of which the percentage of reduction varied from 0·10 to 1·30.

The cuttings from a lathe when they were produced from an annular groove, by means of a straight tool, assumed exactly the same forms. For example, a cutting from a groove in what is called the Swedish piston is a continuous ribbon rolled up as on a bobbin, with the greatest regularity, and of great length, without a rent.

When turnings take the form of a helix, the small lateral displacement of the piece is not large enough to give to the ribbon a different character to that of a planing machine, when, for instance, it is required to turn a shaft to a uniform diameter, and it is then easy, with good metal, to produce cuttings of great length. But, when it is required to turn the end of the shaft or of any cylinder whatever, the cutting follows a special course. If the tool be large in proportion to the diameter of the rings or circles on which it is acting, the difference of diameter between the two edges of the cutting makes itself felt in the cutting, which assumed the form of a helicoidal surface, with inclined generating lines, of which the directrices are two helices of the same pitch but of different diameters. This universal geometrical character, moreover, is manifested in special ways according to the width of the ribbon and the interior diameter of the ring. In this way three horns may be obtained, encased one in the other, if the cutting edge of the tool be radial. Successive spirals foul each other when the direction of the cutting edge is a little inclined. The inner helix is replaced by a straight edge when the tool cuts right to the centre of the face.

Notwithstanding these differences of detail, the same rules prevail: a greater or less reduction or shortening, according to the thickness of the cutting; a less reduction of length at the thicker edge of the cutting; a smooth surface of separation, which always forms a developable surface; a rugged reverse face ridged as if waves of metal had been successively projected there; in fact, all the circumstances of a transverse flow of material—setting apart the secondary circumstances, of transformation of the prism of metal from which the cutting is produced by augmentation of thickness and corresponding reduction of length.

The author endeavored to represent, by a diagram, the triangular cutting which would be formed by planing from the edge of a block of metal a square prism, by means of a tool having two cutting edges, and of which the flat front is itself placed symmetrically. The effect of the diagram, constructed on the assumption of a percentage of 0·30, is exactly reproduced by the model in relief. In agreement with the foregoing discussion and with the facts, it may be observed how the prism which is on the point of being separated from the block swells up by compression, commencing at a certain zone of fluidity, of limited length, in advance of the tool; and how, when this compression has arrived geometrically at the maximum which could be sustained by the material, the cutting is detached from the mass to be subjected to the action of the face of the tool, upon which it slides, and which forces it to assume its ultimate form.

Considerable as these modifications may appear, they are absolutely in accordance with the facts. They have been produced by the author, on lead as well as on the hard metals, under conditions which were exactly proportional to those which are represented by the model.

The finest specimens of this triangular transformation of cuttings that have come under the author's observation, are produced by a mortising tool. They are not less than $\frac{6}{10}$ inch thick, and the rolling up of the metal could only be effected with the accompaniment of deep fissures in the lateral edges. The upper edge, on the contrary, is much more minutely serrated, one of the lateral faces is plaited for its whole length, evidence of the compression of the material; whilst the other face, with its oblique fissures, shows still better the sliding by means of which the compression takes effect.

There is a still smaller cutting which presents exactly the same characteristics.

It is the author's opinion, that for the construction of the best machine tools, with the most suitable thickness of cuts, the minute examination of the cuttings is of the greatest importance; and that by the same means, the surest evidence may be derived with respect to the qualities and homogeneity of the metal.

Time does not permit of more than a passing reference to certain deformations which recall to mind, with a surprising degree of exactness, the constitution of certain rocks with their dislocations. A few experiments of this kind were made by the author in conjunction with M. Daubrée, from which the latter gentleman quite recently derived an explanation of a number of geological phenomena. The results of these inquiries would no doubt possess some interest for the members, but the author was desirous chiefly to lay before them such results of his investigations as followed in natural sequence upon the substance of the communication already made in 1867.

The idea of the flow of solids is, of all the modes of regarding their deformation, perhaps the one which most truly interprets all the phenomena of molecular mechanics, and of the internal constitution of bodies, which underlie the various industrial operations.

ON THE DIRECT PROCESS OF MAKING WROUGHT-IRON AND STEEL.[1]

By CHARLES M. DUPUY, C. E.

[Second Paper.]

About one year ago I had the honor of addressing this Institute on the direct manufacture of iron from the ore. I then briefly referred to the various efforts that had been made in that direction, reaching over the best part of the past century, and closed the paper by describing a method, which, from various experimental and practical tests, seemed likely to promise usefulness in the arts.

It may be remembered, by this process the ore, carbonaceous matter and fluxes, in the proper proportions, are ground together and mixed at the same time, and then filled into annular sheet-iron cases, holding from 100 to 200 pounds. Ten to twenty of these cases, with spaces between them, are subjected to the gradually increasing heat

[1] A paper read before the meeting of the Franklin Institute, Nov. 20th, 1878.

of a reverberatory furnace, and in about five hours, on the average, the ore and cases settle down, without work upon them, to about one-third their original height, becoming welded into quite compact lumps of iron, interspersed with liquid slag. These metal lumps are either then removed separately from the furnace, or several of them being welded together at the same heat, are forged or squeezed and rolled to "muck-bar."

This process differs from all others, and it is exactly the reverse of the forge-fire and the blast-furnace methods. In *those*, a tuyere conducts a stream of oxygen into close contact with the particles of ore, while in *this* process the moderate heat prevents the combination of phosphorus with the iron, while atmospheric contact is excluded during reduction, and a reflected heat from the roof is furnished, for absorption during the transition to metal. It is to this peculiar treatment that is ascribed the high quality of the iron for steel purposes. It is what may be termed a *baking* process, which is conducted at a comparatively moderate heat to *eliminate phosphorus*, and in which the ore is kept out of the reach of oxidizing influences, and to this the high value for steel is attributable.

At the time I addressed you I had licensed Messrs. Miller, Metcalf & Parkin, of Pittsburg, Pa., to work the process at their Crescent Steel Works. Their forge and furnace was not completed until some time in last January, when for several months thereafter they carefully tested the iron which was deoxidized with charcoal by this method, in the various ways customary to determine the value of iron for high grades of steel. The result of these investigations brought forth the unqualified endorsement of this firm that the iron so produced from our native ores, for steel purposes, is equal in every respect to the most costly grades of Swedish iron.

Although the production of fine steel iron, reduced with charcoal by this process, was a step forward, yet the consumption of high grades of steel is comparatively limited, being mostly used only for tools of various kinds requiring great endurance. In order to enlarge the uses of this superior make of iron, it became apparent that its cost must be cheapened by deoxidizing the ore with waste anthracite dust or refuse coke-dust, instead of charcoal.

To determine the practical value of anthracite dust, a series of more than fifty experiments were conducted, during the month of August last, at the forge at Reading, Pa. In these experiments,

with anthracite dust, were used magnetic ore from near West Point, N. Y., Dickinson ore from northern New Jersey, Cornwall ore from Lebanon Co., Pa., Cumberland Valley ore, from Maryland, Hematite ore from near Newark, Del., beside several other ores found near the line of the Phila. and Reading R. R.

These ores were worked both separately and variously combined, and with one exception, in every case, were reduced and forged to blooms. The blooms, which were reheated, were drawn out smoothly under the hammer. The tensile strength of one of these bars was tried, and found to not exceed 45,000 pounds to the square inch.

A couple of crucibles of steel were made from a part of the iron which had been reheated and drawn out, and the ingots were forged and used for planing tools. They stood forging and tempering well, comparing favorably, in endurance, with steel usually used in planing iron.

The object of testing iron reduced from the ore with *anthracite* coal-dust, for tool steel, was not so much with the expectation that at the first trial it would work well in planing iron in competition with steel carefully prepared from *charcoal* iron, but to determine, in a general way, the quality of the metal for steel purposes, of superior quality and in large quantities, by the open hearth. The result of this crucible test surpassed expectations and was very gratifying, from the fact that it is believed to have been the first instance where good tool steel was ever made by a direct process, on a practical scale, from iron deoxidized with *anthracite coal-dust*, and confirms the belief that anthracite dust will eventually be largely used to produce steel of high quality, cheaply, and in large quantities.

Besides testing the ores before named, at the Reading forge, iron scale from the rolls (which is almost pure oxide of iron) was reduced alone with anthracite dust, and was also mingled with ore and anthracite, and in both cases was found to forge well into good blooms.

At the same time with the foregoing experiments, the sulpho-oxides or refuse ore, remaining after extracting sulphur for sulphuric acid from the iron pyrites, at the New Jersey Chemical Works (commonly known to the trade as "Blue Billy"), was also reduced by this process with anthracite coal-dust, and forged well into a bloom. This specimen was sometime afterwards reheated, rolled, cut up and piled with about one-third of its weight of muck-bar from

common puddled iron, and plated out well into smooth sheets of No. 26 iron. This last experiment is not of much value for this country, because very little sulphuric acid is made from pyrites, but in Europe probably not less than a million tons of this refuse ore is now annually almost wasted, because of the difficulty of economically utilizing it.

These Reading experiments were the more gratifying from the fact that the process was quite successfully conducted in a reverberatory furnace, not well adapted to the purpose. This furnace had some time before been specially arranged to test the use of anthracite coal-slack, by burning it in fires of four or five inches thickness, on what is commonly termed "the Wooten grate-bars." As these thin fires required renewal every fifteen or twenty minutes, the frequent opening of the door for replenishment exposed the ore so often to atmospheric reoxidation, as to make the furnace unsuited to the process. Besides this, the fire and flue bridge-walls, which had been constructed very low, and could not be very well raised owing to the lowness of the roof, caused the cases of ore to be exposed to the direct action of the blast and draft as it passed through the furnace into the stack.

Following up these interesting experiments, during the month of September last, a sand-bottom scrap-heating furnace was altered at the Sligo Iron Works at Pittsburg, for the purpose of testing this process further, by throwing the lumps of metal into a Burden Squeezer, and then rolling them to "muck-bar" at the same heat. Hitherto they had usually been forged to blooms under a hammer and afterwards reheated, to be drawn to bars.

This furnace was operated experimentally with 32 heats. There was found no difficulty in making balls to pass through the squeezer and muck rolls at the same heat, just as ordinary puddle balls from pig-iron is squeezed and rolled at the same heat to muck-bar, but in order to fill the squeezer, which required balls of 150 to 200 pounds to secure a good compression, it became necessary to weld and press several of the lumps of metal together, in the furnace, at a heat so high, as to cause the alkali to drip more or less from the mass, and soften the sand-bottom. As the balls were thus compressed and rolled in the fused sand, an unnecessarily large portion of the iron was thereby cut by the sand, and wasted to a silicate of iron, so that the yield from Republic ore which, before the bottom became softened produced

53 pounds of iron in muck-bar from 100 pounds of ore charged, and which it was expected would have been brought up to 60 pounds of iron from 100 pounds of ore, gradually became very much lessened, showing conclusively that reduced yield followed the softening of the bottom, and determined the necessity of a "*cinder-bottom*" in order to save the iron.

To compress and weld several of these masses of metal together in the furnace, in order to have them enter and fill the squeezer, *really comprised all the labor required during the heat.* The cases were 15 inches diameter and 14 inches high, holding about 135 pounds of ore besides the coke and fluxes. By making the cases very little larger, say 16 inches diameter and 16 inches high they would each produce about 100 pounds of iron, and by withdrawing each separately to the squeezer, all furnace manipulation of the metal would be avoided. Then, aside from maintaining the fire and charging and discharging the metal, all the labor really needed during the heat would be to change the damper once or twice, enabling an ordinary heater, to regulate all the furnaces in the largest mill.

The fire- or grate-surface of this Pittsburg furnace was 4 feet square, and the space between the bridge-walls was 9 feet by 5 feet in width. The bottom was of sand, set hard by heat. The flue-bridge was built up within 3 inches of the roof. The stack was 18 inches square inside. A fan-blast was used, part of the air passing under the grate-bars, and part, being heated, was passed through and over the fire-bridge.

In these several experiments it was found that although the opening between the flue-bridge and roof for the escape of the spent products of combustion, into the stack, was lessened more than one-half the size from what it was, when, with less capacity, the furnace had been used for heating scrap-iron, still the heat was so intense as to soften and render useless the damper rod at the top of the stack, which had previously stood 12 years, requiring renewal three times during these experiments. The conclusion drawn from these accidents, was that the grate-surface of this furnace was amply sufficient to supply the accumulating heat for a length of 14 or 15 feet between the bridge-walls instead of 9 feet, thereby nearly doubling the capacity of the furnace with the same consumption of fuel.

Expensive fluxes, such as soda, manganese, etc., have been abandoned, as it has been now conclusively proved that a proper mixture

of aluminous and silicious ores with lime, to produce a non-flowing glassy slag, is all that is required. This glassy slag, being mingled among the particles of ore, covers and seals them from reoxidation from furnace heat during the process of reduction. When either of these glass-making constituents are not available, in the proper proportion, in the ore, ordinary sand or clay, in the proper proportions, may be added to the lime and mixed together, without injury to the metal, as the glass is readily compressed out of the iron by the hammer or squeezer.

During these experiments, No. 26 sheet-iron was rolled out at the mill from common puddle bar, being found to answer *equally as well for cases* as well finished sheets from the best iron.

It has now been demonstrated that good steel can be made by this process from iron deoxidized either with *charcoal, anthracite dust* or *coke-dust.* The carbon in all these fuels being alike, and as the ash of either, along with the earthy impurities of the ore, be they more or less, may be readily reduced to a glass, by a proper mixture of lime and ores, through chemical analysis, and so utilized as a covering of the metal during deoxidation, and compressed from it afterwards—it follows the truest commercial economy is found in using that form of carbon which is of least value.

In the coke-making bituminous regions, the refuse coke-dust is disposed of in waste heaps and often burnt; while from the beginning of anthracite mining, mountains of anthracite slack remain standing monuments of our wastefulness. These wasted fuels, by this process, offer a premium for the production of cheap steel.

Any process that will not withstand the closest economic scrutiny, is justly recognized as valueless in the arts; it is therefore proper to remark, that the investigations at Reading and Pittsburg during the past year, although conducted in furnaces not specially adapted to the process, and often amid inconveniences inseparable from experiments surrounded by the activity of regular mill-work, still nevertheless substantially confirm the view heretofore asserted, that a true commercial economy cannot fail to result from a systematic working of the process.

When it is considered that this mode of making iron *frees it almost entirely from phosphorus*, which goes almost altogether into the slag as explained in my former paper.

That a furnace at present prices for material and labor, in which from one ton to one and a half tons of blooms may be produced every 24 hours, will not cost over $800 to $1000.

That a little lime in combination with ore and waste coal-slack has been substituted for more expensive fluxes and is found sufficient to supply the glassy covering for the metal.

That No. 26 sheet-iron for cases is now found to be good enough *when plated out from common puddle bar*, and that the cases are very simply and cheaply made, needing neither tops nor bottoms.

That two men, in 10 hours, with a 15 horse-power engine, will grind, mix and fill the cases with the ore mixture for 7 tons of blooms.

That the furnace work is confined to charging, discharging and firing the furnace, *there being no necessity whatever for manipulating the metal from the time it is charged in the furnace until brought to the hammer or squeezer*, thus greatly simplifying and cheapening what by the puddling process is excessively laborious and expensive work.

That the masses of metal, as one by one they are squeezed to blooms, may then be transferred in the heated state, to the open-hearth bath, and there quickly melted along with the other steel-making material for the highest quality of steel.

When all these points are well considered it may be clearly understood that in localities as favorably situated for instance as the line of the Philadelphia and Reading Railroad, where Cornwall and other ores can be laid down at an average of $3 per ton, and where anthracite fuel and coal-dust may be obtained proportionally low—that blooms on a large practical working scale, nearly freed from phosphorus may be manufactured equally as good for $18 or $20 per ton, as now cost from $38 to $50 per ton. Similarly great inducements are likewise offered in Northern New Jersey, where fuel and ore can be brought together at about the same cost. In the bituminous coal region fuel is correspondingly low and coke-dust can be had for the freight, offering favorable manufacturing advantages.

In a few words, this process offers a cheap mode of making a high quality of metal for steel, by an inexpensive plant, enabling manufacturers to utilize idle rolling mills at trifling cost.

TESTS OF BOILER IRON IN THEIR RELATIONS TO THE PROVISIONS OF THE STEAMBOAT LAW.

By JAMES A. DUMONT,[1] Supervising Inspector-General of Steamboats.

One of the most important subjects connected with the steamboat inspection service is contained in the statutes referring to the quality of the iron plates to be used in the construction of boilers,—requiring the manufacturers of boiler-iron to guarantee its tensile strength, homogeneousness and toughness, as well as ability to withstand the effect of repeated heating and cooling,—for the use intended, and imposing pecuniary penalties, as well as imprisonment, for placing false stamps upon the same. Section 4430 R. S., also making it the duty of the Board of Supervising Inspectors to provide means for ascertaining that the law has been complied with, before such iron can be used in the construction of marine boilers; in pursuance thereof, that body has established rules for ascertaining the tensile strain only, leaving the other qualities to be decided by the individual judgment of the inspectors making the tests. The result of this, as asserted by manufacturers, has been to develope a disposition to secure the greatest amount of tensile strain possible, to accomplish which homogeneousness and toughness—elements fully as necessary to safety as tensile strength—have been sacrificed, experience failing to show a single instance of the rejection of boiler-plates, by the inspectors, except for deficiency in tensile strength.

The evils likely to follow such a course can be better understood when it is known that all manufacturers unite in admitting that tensile strength can be *increased* by combinations in the material, which *decrease* the other qualities. In other words, the harder and more brittle the iron, the greater the tensile strength. Many manufacturers assert that iron which shall contain all the requisites specified in the law, cannot be made to exceed 55,000 pounds tensile strain to the sectional square inch, yet by the table of pressures allowed by the Board of Supervising Inspectors, more steam is allowed a *hard, brittle* $\frac{1}{4}$ inch iron than is allowed to iron $\frac{5}{16}$ of an inch in thickness, containing all the lawful qualities, which is certainly wrong and

[1] To be embodied in the Report of the Supervising Inspector-General of Steamboats.

decidedly unsafe if the theory of the manufacturers is correct. Therefore, the necessity is apparent that some definite, and generally acceptable rule should be arrived at for deciding this important matter.

Dr. Charles Huston, of Messrs. Huston, Penrose & Co., Coatesville, Pennsylvania, who has made many experiments with a view to a solution of this problem, and to whom I am indebted for many valuable suggestions, is inclined to think that the reduction of area, produced by tension in ascertaining tensile strength, indicates the possession or lack of the other necessary qualifications, according to the greater or lesser percentage of reduction shown, and that upon a minimum and maximum percentage of such reduction might be based a rule for the rejection of such plates as were below the former, as being too *hard* for boiler purposes.

The Society of Railroad Administration of Germany, has recommended its government to adopt 25 per cent. reduction of area as the standard of boiler iron in that country, on first quality of iron of a minimum breaking strain of 51,213 lbs., from which article, together with the experience acquired in testing the iron of the various manufacturers of this country, I deem it safe to assume that the object sought would be accomplished by adopting a minimum and maximum scale of reduced area at breaking point, demanding increased reduction, with increase of tensile strain with the minimum, for the lowest tensile strain to be not less than 15 per cent. reduction.

Below, I give the results of a series of tests, made in conjunction with Dr. Huston, of Coatesville, each experimenting on alternate samples from the same sheets, the main object of the experiments being for the purpose of ascertaining the relative strength of boiler-plate *with* and *across* the grain, while they show interesting results in many other respects than that for which they were made. In order to illustrate the experiments to the best advantage, they are here presented in the three following tables.

Nos. 124, 125, 148 and 149 were samples of $\frac{3}{8}$ iron, cut exactly the square of the thickness, and Nos. 131 and 132 were of the same iron, whose area approximated one-quarter of one square inch. Nos. 128 and 129 were of $\frac{1}{4}$ inch iron, reduced to the square of its thickness, while Nos. 135 and 136 of the same thickness, were

TABLE 1.—*Tests made at the Treasury Department—American Iron.*

LENGTHWISE OF THE GRAIN.			CROSSWISE OF THE GRAIN.		
Sample No.	Tensile strain per square inch.	Reduced area. Per cent.	Sample No.	Tensile strain per square inch.	Reduced area. Per cent.
	⅜ IN. IRON.			⅜ IN. IRON.	
124	61,481	30	125	58,653	22
132	60,408	47	131	57,377	15
148[1]	56,270	25	149[1]	54,461	17
	¼ IN. IRON.			¼ IN. IRON.	
128	61,538	36	129	59,125	18
136	58,373	38	135	53,383	9
	5/16 IN. IRON.			5/16 IN. IRON.	
126	62,871	38	127	58,765	20
134	62,195	43	133	60,202	10
	½ IN. IRON.			½ IN. IRON.	
146	61,918	33	147	63,469	6

[1] Samples Nos. 148 and 149 American iron, but of different manufacture from the other samples.

TABLE 2.—*Tests made by Manufacturer.*

WITH THE GRAIN.		ACROSS THE GRAIN.	
Tensile Strain per square inch of Section.	Reduced Area. Per cent.	Tensile Strain per square inch of section.	Reduced Area. Per cent.
⅜ IN. IRON.		⅜ IN. IRON.	
60,000	44	61,800	22
59,000	42	57,300	13½
¼ IN. IRON.		¼ IN. IRON.	
55,400	34½	52,300	17½
60,100	34	54,600	11
5/16 IN. IRON.		5/16 IN. IRON.	
57,000	45	56,800	20
63,400	44	55,900	21
½ IN. IRON.		½ IN. IRON.	
60,200	31	53,700	6

TABLE 3.—*Tests made in the Treasury Department—English Iron.*

WITH THE GRAIN.			ACROSS THE GRAIN.		
Sample No.	Strain per square inch of section.	Reduced area. Per cent.	Sample No.	Strain per square inch of section.	Reduced area. Per cent.
	¼ IN. IRON.			¼ IN. IRON.	
150	50,555	16	151	40,792	2
152	54,909	13	153	45,334	5
154	56,600	20	155	50,476	8
156	53,061	17	157	54,040	13
158	52,040	10	159	52,575	7

nearly one inch wide. Nos. 126 and 127, $\frac{5}{16}$ iron, were small, and 133 and 134 of the same thickness, were of the larger area. Nos. 146 and 147 were samples of $\frac{1}{2}$ inch iron, cut the square of its thickness. I am particular in this description, for the purpose of illustrating that the change adopted by the Board in its new rules—adopted the past winter—allowing two samples of different areas to be tested, instead of one, as provided for in the old rules, seems to have developed the fact that the manufacturers have gained nothing by the change; the average breaking weight per square inch of section being 59,621 lbs. in the small samples, and 59,818 in the larger ones, showing a difference of only 197 lbs. in favor of the latter. The average breaking weight of the samples cut lengthwise of the fibre or grain is 61,196 lbs. to the square inch, while that cut crosswise of the fibre or grain, shows an average of only 58,703 lbs. to the square inch, a difference in favor of the first, of 2493 lbs. Duplicate samples of the same iron, broken at the manufactory (see Table No. 2), show nearly the same relative results, namely, 59,300 lbs. with the grain, and but 56,050 lbs. across the grain, a difference of 3243 lbs. in favor of the lengthwise cuttings. The iron broken on the scales at the Treasury Department, shows an average of 2271 lbs. greater tensile strain than do those broken on the manufacturer's scales, which fact opens a question as to the correctness of either scale, an important matter when it is to be taken into consideration, that not only pecuniary penalties, but imprisonment is likely to follow false stamping.

Samples numbered 150 to 159, inclusive, are ten samples of English manufacture of various brands showing an average breaking weight of 51,038 pounds to the square inch, with an average reduction of area, in the samples lengthwise of the grain of 15 per cent., while that across the grain was only 5 per cent., showing inferiority to the American iron in every respect,—the latter exhibiting a reduction of 38 and 15 per cent., respectively, lengthwise of and across the fibre, in samples broken at the Treasury Department, and 39 and $15\frac{1}{2}$ per cent., respectively, in the manufacturers' results.

The comparison also illustrates, and almost proves, what I have before alluded to, namely, an error in one or the other of the scales, the uniformity of percentage showing an average inequality in the iron taken from different parts of the same sheet. The difference in

the tensile strain must be attributed to defects in the scales of one or both the testing machines used.

The January number of the *London Engineer* contained a report of a series of experiments by Chief Engineer Shock, of the United States Navy, which shows different results from those given here regarding the strength with and across the grain of iron, but the fact that such results are contrary to all former experience, and also to the results here given, would seem to indicate that the iron used by Mr. Shock was of exceptional quality, and that it would be difficult to obtain such results a second time. That being the case, safety would seem to require that boiler-makers should be careful, in working plates into boilers, to see that they are placed so that the greatest strain shall be with the grain of the iron.

Manufacturers would benefit themselves and render valuable assistance to the Board of Supervising Inspectors if they would confer with each other and unite in recommending some standard for determining the lawful qualities of boiler-iron, and submit the same to the Board at its meeting in January next, in order that this body may frame a rule which will make the method of testing iron uniform throughout the United States, thereby protecting themselves as well as the public from the evils of the present system, which makes it possible for an officer who may be prejudiced in his views, to exclude from certain markets certain brands of iron to the injury of the manufacturers thereof, without benefiting the general public.

THE RELATION OF DUCTILITY TO TENSILE STRENGTH IN BOILER-PLATE.

In pursuance of a general call, a convention of boiler-plate manufacturers was held in Philadelphia, November 13th, 1878, and action was taken upon the suggestion of the Supervising Inspector General, contained in the last paragraph of the above paper.

Through the courtesy of Dr. Charles M. Huston, who presided at the meeting, and Mr. W. H. Morris, the secretary, we are able to give the following extract from the proceedings.—EDS.

After some discussion the following resolutions were adopted:

Resolved, That in the judgment of this meeting, plates should not be used in a steamboat boiler, that show a contraction of area less than 12 per cent. We therefore recommend that all boiler-plate, stamped with tensile strain of under 45,000, should show contraction of area of 12 per cent.; 45,000 and under 50,000, should show 15 per cent.

contraction of area; 50,000 tensile strain and under 55,000, 25 per cent.; 55,000 tensile strain and over, should show 35 per cent.

WHEREAS, The question was raised before the meeting of the Board of Supervising Inspectors, at its meeting last January, in regard to the form of test pieces they had adopted, and whereas, the Board, in order to meet the views of the manufacturers, adopted two modes of preparing the test pieces, with a view to ascertain which was right, therefore

Resolved, That the thanks of this meeting be extended to the Board for this act of courtesy, which has resulted in the fact, that there is no practical difference in the two modes.

Resolved, That we respectfully suggest to the Secretary of the Treasury, that test pieces, cut from the plate to be used in steamboat boilers, be all tested, at some central location, by a person appointed by the Secretary of the Treasury, to be under the direction of Supervising Inspector General of Steamboats.

Resolved, That a copy of these resolutions be forwarded to the Supervising Inspector General, duly signed by the President and Secretary.

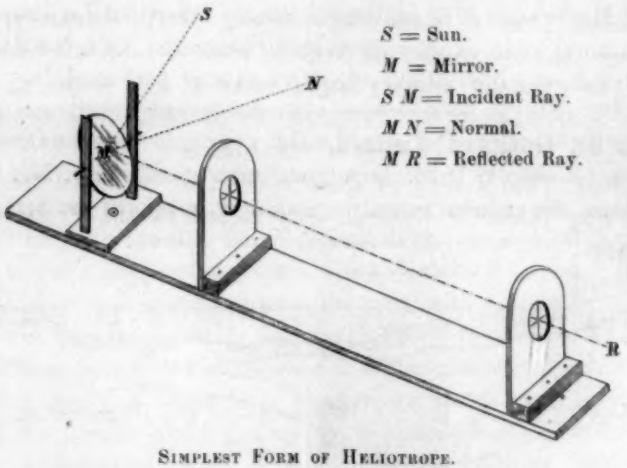
ON THE USE OF THE HELIOTROPE IN GEODETIC SURVEYS.

Contributed by L. M. HAUPT, Professor of Civil Engineering, Towne Scientific School.

The heliotrope is used to reflect the sun's rays to distant points, and thus facilitate the operation of reading angles, either horizontal or vertical, on lines of from 15 to 100 miles in length. The name is derived from ἥλιος the sun, and τροπή turning—hence the instrument is one which turns or deflects the rays in any required direction. It differs from the heliostat in not being automatic.

Its construction is so simple that it may be made by any schoolboy with a penknife. Two opaque screens are placed about 18 inches apart upon a strip of wood forming a base and screwed or nailed fast. A hole about one inch in diameter should be cut through each screen, the one in rear being a little larger than the other, and across each there should be drawn two fine wires or threads so as to intersect each other.

About six inches in rear of the screens there should be placed a small mirror, 3 inches in diameter will be sufficient, so mounted as to have the two motions horizontal (or in azimuth) and vertical (or in altitude). The crude instrument is then ready for operation. To throw the ray upon any given object visible to the unaided eye, turn the mirror down out of the way or remove it altogether, and sight across the wires, moving the base until the line joining the intersections of the cross wires passes through the object. Then replace the mirror carefully so as not to disturb the line of sight, and turn it in either or both directions until the shadow of the edge of the hole in



Simplest Form of Heliotrope.

the first screen is concentric with that in the second. The reflected ray will then be visible to an observer at the given point.

When the observer is so distant that a telescope is necessary to determine the direction to him, the instrument is modified by attaching the rings and mirror to the telescope, care being taken that the axis of the rings is parallel to that of the instrument. Should the sun be in the plane of the mirror or back of it so that no reflection can be obtained, an auxiliary mirror must be used and placed in such a position as to reflect the ray upon the primary mirror which, by a second reflection, sends it through the rings.

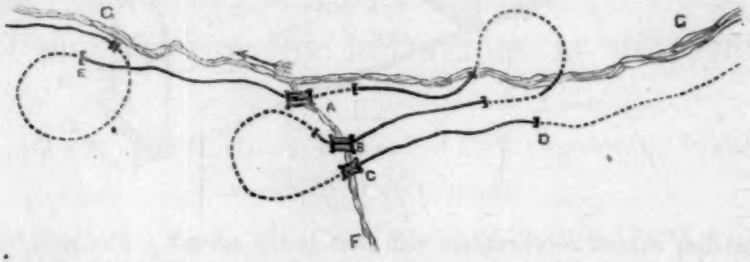
Although so simple and inexpensive, this little instrument serves to increase greatly the economy and accuracy of reading angles to very distant objects. The rays reflected from it are plainly visible to

the naked eye at from 30 to 50 miles, and with telescopes these "day stars" have been seen at a distance of nearly 100 miles across Lake Superior when no trace of land was visible.

It needs no second thought to perceive that they may be used as were the semaphores of Claude Chappé introduced in 1794 as the first efficient *telegraph*, but with greater effect. By adopting any convenient code of long and short flashes made by obscuring the ray, messages may be sent from point to point. In one instance a vessel was saved by signaling to a party at Marquette, Lake Superior, that she had grounded on some rocks near the station "Vulcan" on Keweenaw Point.

The Morse code is as convenient as any other, but for simplicity a conventional code expressing certain sentences by a few flashes is found to answer the ordinary requirements of field work.

The St. Gothard Tunnel.—In a private letter written from Geneva, October 1, 1878, to a gentleman of this city, Mr. Walton W. Evans, the eminent consulting engineer, speaks of the St. Gothard tunnel, now in course of construction, as follows: * * "I went



over the St. Gothard Railway with the engineer, as far as the big tunnel, to see the most difficult railway works ever attempted in the world; nearly one-third of the whole line is in tunnels. In some places the railway is put in tunnels to get it out of the reach of avalanches; in one case the engineer pointed out to me, as we were riding on the highway, 60 to 70 feet above the river, the place where an avalanche came down last summer, filling the whole valley, and coming up into the road where our carriage was. I will enclose to you a sketch of a piece of the location of this railway, taken from their map. Their fixed maximum gradient is 1 in 40; their fixed minimum radius of curvature is 1000 metres. There are no side valleys to run up and back again to get distance, and as the valley

in some places rises faster than the fixed gradient allows, the engineers are forced to tunnel into the sides of the mountains in entire circles (corkscrew circles) to get distance. The sketch I enclose shows three of these circular tunnels, about 8 kilos. north of the big tunnel.

"The waved lines show water-courses, *G G*, being the River Reuss. The full lines show the location of the railway lines, and the dotted lines the tunnels. The points *A*, *B* and *C* show bridges over a cascade. The bridge at *B* is about 500 feet above the bridge at *A*, and the bridge at *C* is about 300 feet above that at *B*. The circles in the tunnels are 2000 metres, or 6502 feet diameter.

"On the south or Italian side of the big tunnel, are more difficult locations still. The roads here are beautiful; built and kept in order by the State. All their work is well done.

"The tunnels of this railway (even the big tunnel is solid granite, and wide enough for three tracks) are arched with granite, but little inferior to the face-work of the Astor House. You can imagine that none but the rich nations of Europe could, for a moment, think of building such a railway.

"I was run into the big tunnel for 2 kilos., on one of their air engines, to see a drilling machine I once explained to you. Baron Lauber tells me it is pressed against the rock with a pressure of 130 atmospheres, and that it walks into granite as if it were cheese."

* * In regard to the abundance of water-power in Switzerland, Mr. Evans says: "There is a tremendous water-power going to waste all over Switzerland; you can see in hundreds of places streams of water coming down nearly perpendicular for 1000 or 2000 feet. At the great tunnel of the St. Gothard Railway, the River Reuss crosses the very mouth of the tunnel, and gives the engineers a water-power fifty times greater than they can use for compressing air, making repairs, etc., etc." * * S.

Automatic Switch for the Jablochkoff Candle.—Jablochkoff has introduced a new automatic switch in his lamps. A bell crank lever has a platinum rod at one end, which is pressed by a spring against the isolating mass between the two carbons. As soon as the candle burns below this point, the spring throws the lever over; the current passes through the other arm of the lever, which becomes part of the circuit, to the second candle; and a new one may be substituted for the first.—*Journal für Gasbeleuchtung*, etc. P.

The Determination of Carbonic Acid in Air to be Breathed.[1] —Dr. Pettenkofer, of Munich, has found that carbonic acid accumulates in a room in almost the same ratio as impurities resulting from breathing and other exhalations from human beings. The percentage of carbonic acid consequently indicates the degree of impurity, provided the gas is not generated artificially. Atmospheric air contains about $\frac{4}{10}$ volumes per mille. Dr. Pettenkofer places the extreme limit of admixture of good air for breathing in a room at 1 per mille.

In imperfectly ventilated schoolrooms it has been found as high as 10 per mille.

Dr. Pettenkofer found that the air of a room of 75 cubic metres contents, all windows and doors being closed, was entirely renewed each hour; and that after hermetically closing door and window cracks, it still continued at the rate of $\frac{3}{4}$ the volume of the room per hour. This was with an outside temperature of — 1° (most probably Centigrade) and + 18° in the room—consequently a difference of 19°. This must take place through the pores of the walls.

To determine the renewal of the air, he made use of the admixture of known quantities of carbonic acid. He allowed the gas to enter the room; it diffuses itself through the air. A chemical analysis of the air then indicates how rapidly the new air passes in, for as soon as the percentage sinks to the normal quantity of ordinary atmospheric air, the whole volume has evidently been replaced. The time in which this takes place gives an approximate estimate of the rapidity with which the outer air enters.

Experiments made in France about thirty years ago, showed that about 60 cubic metres of fresh air per person were needed each hour, in order that no offensive odors should arise in a crowded room. Dr. Pettenkofer arrives at the same result by chemically analyzing the air and measuring the percentage of carbonic acid, then determining the quantity of fresh air necessary to keep it within 1 per mille in a room full of people. This quantity is very large, as only $\frac{1}{2}$ cubic meter is needed for breathing by each adult per hour. But the impurities are rapidly diffused through the air, and render it unfit for breathing.

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[1] From a paper read by F. Paul, Engineer, at the meeting of the Austrian Society of Engineers and Architects, February 14th and April 11th, 1878, and published in No. IX of their journal.

According to Dr. Pettenkofer the best French authorities give the following quantities of pure air as necessary, per hour, for each individual:

In hospitals (ordinary invalids),	60–70	cubic metres.
" (for the wounded),	100	"
" (epidemic diseases),	150	"
In prisons,	50	"
In workshops (ordinary),	60	"
" (in unhealthy locations),	100	"
In barracks (by day),	30	"
" (by night),	40–50	"
In theatres,	40–50	"
In halls (for long sessions),	60	"
" (for short sessions),	30	"
In schools (for children),	12–15	"
" (for adults),	25–30	"

P.

Electric Lighting.—In reviewing the present state of electric lighting, the *Journal für Gasbeleuchtung*, etc., says:

Its practical utility as an illuminating agent has only been acknowledged since means have been discovered, 1st, to generate the electric current at a relatively low cost; 2d, to produce an almost constant light; 3d, to subdivide the light.

The first decisive step towards giving the electric light its present undeniable importance, was the substitution of the magneto-electric and dynamo-electric machines for galvanic batteries.

Owing to the more rapid and irregular wasting of the positive carbon pencil, different mechanical arrangements were designed to keep the points at a constant distance from each other. Serrin's lamp has been principally used, till last year, when Jablochkoff gave a new complexion to the whole subject by his invention. He places the carbons beside each other, and isolates them with a mass, solid at ordinary temperatures, but fusing at such as are necessary for the production of the voltaic arc, and becoming then a good conductor. Powdered glass and kaolin have been used for this purpose, but lately other preparations have been substituted, partly to render the color of the light more agreeable, partly to obtain greater steadiness.

This property of the isolating mass enables the current to be subdivided. Besides, the improved machines can also generate several currents, so that each may be used to operate several lamps.

For instance: the 48 lamps which illuminate the Avenue and Place de l'Opera, Paris, are operated by three machines, each furnishing four independent currents, and each of the latter feeding a group of four lamps. Each lamp has four carbon candles on a turn-table, so that when one wastes away (in about 1½ hours, the machine working uniformly) a new one can be placed in position by turning a crank. The whole arrangement is enclosed by thick ground glass. To ignite the carbon, a piece is laid on top, which is rapidly consumed.

The copper wires from the machines are covered with gutta-percha, carried underground through earthenware pipes, and isolated every half-metre by the supports. Four wires run from each of these main wires to each of the four carbon pencils of a lamp; the current then is led by a single wire to the next lamp, then to the third, to the fourth, and finally back to the machine.

The lamps operate 6 hours, when gas is substituted. At least one horse-power is regarded as necessary to operate a lamp. Its intensity is considered as equal to that of 100 gas-jets (each consuming 105 litres per hour). But this is only partly true, as the gas-flames must be regarded as concentrated at one point. If a given enclosure is illuminated by a number of gas-jets, and then by the electric lamp, the latter cannot replace more than 30 jets; generally less—between 20 and 30.

A great advantage is the almost complete immunity from danger of fire and the small quantity of heat evolved.

The city of Paris pays 1 fr. 45 c. per hour for each lamp, which nominally gives a light of an intensity of 100 gas-jets. The scientific journals, however, state that the real intensity is equal to no more than 20 jets, with a total consumption of 2·8 cubic metres per hour.

Further taking into account that two main wires must be laid to each lamp, with four branch wires; that every 1½ hours a new carbon candle must be brought into position by hand; further, that one machine, requiring one horse-power, is needed for every four lamps, and cannot be placed at one centre with others, as it is impracticable; and finally, the unreliable nature of the steam motive-power which generates the light; no one will seriously think that street-lighting can at present be accomplished.

For lighthouses, large open squares, workshops, depots, theatres, and large halls, it may be adapted, and in those cases it will compete with gas. P.

A Novel and Simple Method of taking Specific Gravities.—M. Gannal has recently devised a means of determining exactly, and with the greatest facility, the specific gravity of all liquids.

With his "*densimetre hydrostatique*" all calculation is obviated, and the specific gravity is ascertained by simply reading the weight on the balance.

This useful and ingenious apparatus is made in the form of an *olive*, so that bubbles of air shall not attach themselves to its sides.

The olive (whether made of glass or metal) has a volume exactly equal to one decimal subdivision of a cubic metre. There are two different methods employed in the practical use of the apparatus:

1st. We may suspend it on the platform of the balance, and after having produced an equilibrium we plunge it into the liquid, the equilibrium is then destroyed by the loss of weight of the olive, and the number of grammes which it is necessary to add to the scale pan to restore the equilibrium, is the exact specific gravity of the liquid.

2d. Or we may equally well adopt the following plan: We put the liquid whose specific gravity we desire to ascertain, in a glass vessel on one pan of the balance; we balance the scale pans, and then suspend the olive in the liquid by means of a fine thread. The equilibrium is destroyed, and the scale descends on the side on which the olive is suspended, and the weight—which it is necessary to place in the other pan to restore the equilibrium—is equal to the specific gravity of the liquid.

This apparatus will determine the density of all liquids whether they be heavier or lighter than water, whether they be acids, alcoholics, thick or syrupy. It advantageously supersedes the areometers; it is not fragile, and it gives the indications with an exactitude depending on the sensibility of the balance employed. The work is reduced to a simple weighing and reading of the weights on the balance.

M. A. Gannal has constructed instruments of 100 cubic centimetres, and 10 cubic centimetres only. The larger apparatus is the one which will prove the most convenient and the most needed in commercial and industrial determinations. With this instrument, and a balance sensitive to one decigramme, we may determine the density to the thousandth degree.—*Les Mondes*, Sept. 26th, 1878.

O.

Transit of Mercury, at Rio Janeiro.—Dom Pedro was one of the observers of the late transit of Mercury, at the Imperial Observatory of Rio Janeiro. The contacts were perceived and noted simultaneously by the Emperor and all of the other observers. Liais's new method was employed, and the result differed from calculation by less than $\frac{1}{3}$ of one per cent. in right ascension, and by only $\frac{1}{10}$ of one per cent. in declination.—*Comptes Rendus.* C.

New Laws of Expansion.—M. M. Levy deduces from the two fundamental propositions of thermo-dynamics, the following corollaries: 1. The internal heat of a body cannot be any single function of the specific volume and of the temperature of that body; it can only be the sum of two functions; one of the volume alone, the other of the temperature alone. 2. The same thing is true of the quantity which Clausius has designated as the *entropy*. 3. Hence, the pressure which any body supports, so long as the body does not change its state, can be only a linear function of its temperature; in other words, if any body whatever is heated, under constant volume, the pressure which it exerts on the immovable walls of its enclosure can increase only in proportion to its temperature.—*Comptes Rendus.* C.

Amber Varnish.—S. Meredith prepares a varnish which gives a very fine polish, and which is especially valuable for carriages and for choice furniture. He puts 7 pounds of amber in a clay crucible, with 14 pounds of rock salt, adding water enough to dissolve the salt. He then adds more water, and keeps the crucible over a fire until the amber becomes perfectly white. The bleached amber is put into an iron pot, and warmed over an ordinary fire until it is completely dissolved; the pot is then allowed to cool, and the amber is placed in a stream of water, to remove the salt; it is then reheated until it dissolves, when it is poured on a marble table to evaporate the water, and then exposed to a greater heat to drive off all moisture. This bleached amber is powdered, and then melted in an iron pot. Fine nut oil is added, and stirred until the mixture is complete. The pot is then removed from the fire, and, when sufficiently cool, spirits of turpentine is added to produce the proper consistency. The following proportions are recommended: White amber, 1 lb.; fine nut oil, 1lb.; spirits of turpentine, 2 lbs.—*Les Mondes.* C.

Koerting Blowers.—A. Scheurer-Kestner has reported some experiments with Koerting blowers under various conditions of temperature and pressure. The greater the pressure in the generator, the greater is the useful effect of the vapor. In one experiment, with a boiler pressure of 5 kilogrammes (11·02 lbs.), temperature of the gaseous mixture 31·1° (88° F.), temperature of surrounding air 22·3° (72·1° F.), 8·6 per cent. of vapor carried 91·4 per cent. of air.—*Bull. de la Soc. Ind.* C.

Scientific Skepticism.—M. Bouillaud finds it so difficult to accept the ordinary explanations of the phonograph and the telephone, that he propounds some new and curious hypotheses. He asks whether it is really the phonograph that repeats the sound; whether the repetition is not due either to some kind of echo, or to unconscious action in the vocal organs of the bystanders; and whether the telephone does not act simply as a good conductor of sound, independently of any electric currents.—*Comptes Rendus.* C.

Paper-Sizing.—C. Wurster, in a prize memoir, recommends the use of a preparation of soda and resin, in such proportions that some of the latter material may remain uncombined, so as to have a solution of resin in resin-soap. If this preparation is diluted with water, it forms a milky liquid, which owes its appearance to the resin that is suspended in a state of extreme division. It is especially important, before adding alum, to have the greatest possible quantity of free resin, because the quantity of fibre which the sizing will cover is proportional to the minuteness of the impalpable particles.—*Bull. de la Soc. Ind.* C.

Wood-Staining.—Wood may be stained *brown* by a concentrated aqueous solution of permanganate of potash; *red:* boil ¼ lb. of logwood and ½ oz. of soda, in 1 pt. of water; apply it hot, and then wash it over with a strong aqueous solution of alum; *rose:* iodide of potash in 12 parts of water for a first coat, and corrosive sublimate in 40 parts of water for a second; *blue:* indigo solution, or a concentrated hot solution of blue vitriol, followed by a dip in a solution of washing soda; *yellow:* turmeric, dissolved in wood-naphtha, or aqua regia in 3 parts of water; *green:* verdigris, dissolved in 4 parts of water.—*Fortsch. d. Zeit.* C.

Pocket Microphone.—M. Trouvé has invented a cylindrical microphone, which resembles a small dark-lantern, with a carbon crayon substituted for the candle. When placed in the middle of a room, it reveals all secrets. It transmits the voice admirably to a receiving telephone, even when the speaker stands 25 metres (82 ft.) or more from the microphone. When a watch is placed in the interior, it seems to be making unheard-of efforts to get out. The instrument can be easily used for revealing the normal or morbid movements of the heart or lungs.—*La Nature.* C.

Phonic Wheel.—P. Lacour has devised a toothed wheel of soft iron, which turns on its axis so that its teeth pass near one pole of an electro-magnet without touching it. An intermitting electric current, regulated by the vibrations of a reed or tuning-fork, traverses the coils of the magnet, so that it periodically attracts the nearest tooth. The wheel, turning with such velocity as to traverse the space between two teeth at each period of the current, maintains a uniform movement. It is well-fitted for use as a chronograph, for finding the number of vibrations in a given musical note, and for establishing synchronism in telegraphy.—*Comptes Rendus.* C.

New Telephonic Transmitter.—P. Dumont combines a thread telephone, with a carbon-electric microphone. A parchment membrane, 12 centimetres (4·7 inches) in diameter, is stretched over a vertical frame. At the centre a thread is fastened by a knot at one end, the other end passing over a small pulley, and supporting at its lower extremity a brass cone, suspended by a hook fixed in the centre of its base. This cone, weighing 20 grammes (308·65 grains), penetrates by its point to a depth of about 1 millimetre, into a metallic die filled with dust of gas-carbon, and fixed on the horizontal base which supports the diaphragm-frame. One of the poles of the battery (four Leclanché elements) communicates with the metallic cone, the other with the die. The least variations impressed on the membrane by the sound-waves modify, by the intervention of the pulley, the pressure of the cone on the carbon-dust, and thus produce variations in the intensity of the current, followed by a distinct reproduction of all the sounds in a receiving telephone.—*Comptes Rendus.* C.

Solidification of Petroleum.—Even the lightest petroleums may be partially solidified, by mixing them with an aqueous decoction of soapwort. A mucilage forms, which is so thick that the containing vessel can be overturned without any portion running out. If a few drops of phenic acid are stirred into the mucilage, it soon becomes liquid again.—*La Nature.* C.

Signals for Daltonists.—M. Dherbes, who is himself afflicted with Daltonism, finds no difficulty in distinguishing the following colors, when they are distinctly marked: Sky-blue, bright yellow, scarlet. He therefore proposes the adoption of those tints for luminous signals, or the employment of signals of different forms, *e. g.*, square, triangular, circular, etc.—*Comptes Rendus.* C.

Mean Distance of Water Molecules.—In connection with electrical investigations, Hermann Herwig has made an extended series of observations, with a view of obtaining a nearer approximation to molecular distances in fluids. He concludes that no two molecular layers in water can be more than 1·86 of a millionth of a milimetre apart, and that the same is true with regard to the mean distances of adjacent molecular centres. Sir Wm. Thomson had previously estimated the least value of the same distances at ·05 millionths of a milimetre. These two estimates, one being less than four-fold the other, furnish satisfactory approximations to the true value.—*Ann. der Phys. u. Chem.* C.

Daily Shifting of Levels.—During the past spring Plantamour was induced to make some observations upon the displacement of the bubble in spirit-levels, and he found that there was a daily maximum during the afternoon, accompanied by gradual changes, which extended over a period of several successive days. In confirmation of his observations, M. d'Abbadie reported his own experience at Olinda, Brazil, in 1837; at Gondar, Ethiopia, in 1842; and subsequently, at Saqa. At each of these places the bubbles of the levels showed small variations in the direction of the plumb-line. Astronomers have, doubtless, often suffered from these changes, without being aware of their cause, and have been obliged to mask them by taking the means of frequent observations.—*Comptes Rendus.* C.

Electric Light in Farming.—M. Albaret has invented an apparatus for the application of electric light to agricultural labors. A portable engine, of 4 or 5 horse-power, carries a mast, 20 or 25 metres (65·6 or 82 ft.) high, and drives a Gramme machine. The electricity is conducted to the regulator of the light, in a lantern at the top of the mast. The mast, which is composed of numerous iron tubes, is raised or lowered at pleasure by a winch at its base. The lantern is connected with pulleys, so that it can be brought down without lowering the mast.—*Les Mondes.* C.

Optical Thermometer.—Fizeau, de Lang and Sohncke have experimented on the rotatory power of quartz, between 0° and 100° (32° and 212° F.). Joubert has extended the investigation from — 20° to about 1500° (— 4° to 2732° F.). He finds the law of angular deviation so simple that he recommends quartz as a very simple thermometer and one that especially satisfies the essential condition for every thermometer, comparability. When the apparatus is once prepared, the simple reading of an angle and the employment of a table, which has been calculated once for all, give the temperature.—*Comptes Rendus.* C.

Postal Items.—The number of letters mailed annually, is estimated at 4000 millions. The German post-offices alone delivers 300 millions in a year. Wax tablets are first mentioned in the sixth book of the Iliad. The Egyptian papyrus was, for a long time, very dear. In the time of Pericles a medium-sized sheet cost $1.50. Parchment was introduced in the 3d century B. C.; paper was made from rags in Italy, A. D., 1314. The first German paper-mill was erected at Mainz. Letters assumed their present form in the 14th century. Envelopes were invented in 1820. In 1866, Dr. Stephan invented the postal card, of which 400 millions are now annually used in Europe. Cyrus established the first horse mail. Carrier-pigeons were first used in the East. Rome used private letter-carriers in the time of the Republic. Letters from Africa required 15 to 20 days; from Asia, 40 days. Augustus established the first public mail. The mail-messengers were called *equites positi*, hence the name "post." The German-Austrian postal union began in 1850. The world's postal union now embraces 20 million square miles of territory.—*Dingler's Journal.* C.

Franklin Institute.

HALL OF THE INSTITUTE, Nov. 20th, 1878.

The stated meeting was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers, in the chair.

There were present 138 members and 51 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting there were 11 persons elected members of the Institute, and the following donations to the Library were reported:

British Patent Specifications and Drawings, Nos. 1584 and 1779, and Vols. 21–45, 1877.

British Patent Abridgments relating to Paper, etc., Part 2, 1859; Tea, Coffee, etc, 1704–1866; Chains, Chain Cables, etc., 1867–1876; Dressing and Finishing Woven Fabrics, 1620–1866.

British Patents. Alphabetical Index for 1876.

British Patents. Disclaimers, Nos. 336, 1869; 161, 1870; 2397, 1871; 1527, 2456, 1872; 412, 599, 2171, 1875; 828, 977, 1339, 2764, 4499, 4553, 4746, 5064, 1876; 1860, 3096, 1877.

From Commissioners of Patents, London.

Instructions to Meteorological Observers in India, by H. F. Blanford, Calcutta, 1876.

Tables (5) of Meteorological Results at the Observatories.

Tables for the Reduction of Meteorological Observations in India, by H. F. Blanford, Calcutta, 1876.

Meteorology of Bombay Presidency, by Chas. Chambers, London, 1878.

Meteorology of Bombay Presidency, Diagrams and Maps.

From Meteorological Department, Calcutta, India.

Catalogue of the Library United States Patent Office, Washington, 1878.

Annual Report of the Commissioner of Patents for 1877, containing Index to Official Gazette for 1877. Washington. 1878.

Index to Official Gazette for January to June, 1878. Washington, 1878.

Specifications and Drawings of Patents, for April and May, 1878. Washington, 1878. From Hon. Commissioner of Patents.

American Ephemeris and Nautical Almanac for 1881.

From Secretary of Navy.

Lecons Cliniques sur les Maladies du Cœur, par P. F. DeCosta Alvarenga, Lisbonne, 1878.

Journal de Sciencias, Mathematicas, Physicas e Natureas, Nos. 21 and 22. From Royal Academy of Science, Lisbonne, Portugal.

Annual Report of the Chief Engineer of the Water Department of Philadelphia for 1877. From W. H. McFadden, Chief Engineer.

Historical Map of Pennsylvania. Edited by P. W. Sheafer, Philadelphia, 1875. From the Historical Society of Pennsylvania.

Report on the Meteorological Service of the Dominion of Canada for 1877. Ottawa, 1878. From the Meteorological Department.

Directory to the Iron and Steel Works of the United States. September 1st, 1878.
From American Iron and Steel Association, Philadelphia.

Report of Prof. A. D. Bache, showing the progress of Coast Survey work for the year 1849.

Patten's Artillery Drill. N. Y., 1863.

Memoir of Quamino Buccau, by W. J. Allinson. Philad'a.

Chemistry in its application to agriculture and physiology, by J. Liebig. Philad'a, 1843.

Map of the State of New York. Published by S. A. Mitchell. Philad'a, 1831. From D. S. Holman.

Fonetic Magazine, devoted to the interests of education. Edited by E & S. Longli. London, 1848–50. Vols. 1 and 2.

Phonetic Journal, for 1850 and 1852. Vols. 9 and 10.

Phonotypic Journal, 1843 and 1845. London. Vols. 3 and 4.
From H. T. Child.

Industrial Progress of New South Wales. Sydney, 1871.

Financial Statement of Hon. H. E. Cohen, Treasurer of New South Wales. Sydney, 1878.

Journal and Proceedings of Royal Society of New South Wales. Vol. 11. Sydney, 1878.

Remarks on the sedimentary formations of New South Wales, by W. B. Clarke. Sydney, 1878.

Climate of New South Wales, by H. C. Russell. Sydney, 1877.

Essay of New South Wales, by G. H. Reid. Sydney, 1878.

Annual report of Department of Mines of New South Wales, for 1877. Sydney, 1878.

Railways of New South Wales, by John Rae. Sydney, 1877.

Statistical register of New South Wales, for 1876. Sydney, 1877.

Mineral Map, Pastoral District Map, and Agricultural Map of New South Wales. From R. S. Menamin.

Quarterly report of Chief of Bureau of Statistics. Treas. Dept. Washington, 1878. From Chief of Bureau.

Mr. Chas. M. DuPuy read a second paper on his direct process of making wrought-iron.[i] An interesting discussion followed the reading of the paper, participated in by Messrs. Orr, Loiseau, Jenks, Ware, Pemberton, and the President, during which Mr. DuPuy drew on the blackboard a sketch of the furnace used in connection with his process.

Dr. Isaac Norris, Jr. read a short account of the continuation of his experiments with the microphone, and especially in adapting it to the stethoscope; and exhibited an instrument of this description which had been received with considerable favor by the College of Physicians in this city.

This instrument is in the form of the ordinary Bell telephone, but has the magnet and coil replaced by a metallic tube which can be adjusted endwise by means of the screw at the end of the handle. This tube has a small carbon cup inserted in the end towards the diaphragm.

To the centre of the inner side of the diaphragm is soldered another short tube, also carrying a carbon cup. Each of these tubes is connected by a wire to binding-posts. The two carbon cups are placed about half an inch apart, and a pointed stick of carbon rests lightly in them, thus completing the circuit with a Bell telephone.

This instrument is exceedingly delicate, but has the disadvantage of not working well in all positions.

In the first form of this instrument the carbon in the movable tubes was made pointed, and adjusted to touch very lightly the plane surface of the carbon on the diaphragm, but this was found to require too delicate and frequent adjustment, and was therefore abandoned.

In still another form, a combination of three sets of carbons were employed, but with less satisfactory results than with the single one.

The Secretary's report embraced the Otto Silent Gas Engine,[ii] Moses Burpee's Automatic Car-Coupling; Mrs. M. E. Beasley's Steam Meat Roaster; A. T. Cross' Fountain (stylographic) Pin; and The Organette or Domestic Organ.

The organette consists of a series of reeds placed in suitable passages formed in a block of wood, the inlets being from the under side. These passages are placed over corresponding passages or openings in the top of a wind-chest, supplied by three small bellows

[i] See page 404 ante.

[ii] A full illustrated description of this engine will shortly be published in the JOURNAL.

operated by a triple crank-shaft. A sheet of paper of sufficient width to cover all the passages, has cut through it, openings of such length and distance apart as to correspond to the length and interval between the notes of a tune, when the paper is moved at a rate of speed previously determined upon; the position of the openings in relation to the width of the paper, determining the note or reed to be sounded. The sheet of paper thus perforated, is a perfect graphic representation of the music—the length of the hole representing the length of the note; the space between them, in the same line, representing the interval; and the position, as to the width of the paper, the pitch. The sheet of paper having been properly perforated, has its ends pasted together, forming an endless band, and is drawn along, by means of suitable rollers, between the top of the wind-chest and the bottom of the reed-chest, and as each opening in the paper is brought to coincide with the passage from the wind-chest to the reeds, the corresponding note is sounded.

The sheets of music are inexpensive, and can be easily and quickly changed.

The whole instrument occupies a space of about 18 inches long, 13 inches wide and 8 inches high.

The Secretary presented and explained the memorial of the Engineers' Club of Philadelphia, to the Legislature of the State, asking for the enactment of "such laws as will provide for a thorough Geodetic Survey of the State, and an accurate and permanent location of all county and township lines;" when, on motion of Mr. J. E. Mitchell, it was

Resolved, That in view of the importance of a thorough Geodetic Survey of the State, the Franklin Institute joins in the petition that the Legislature will provide for its prosecution and completion at the earliest practicable time.

Mr. C. S. Close called the attention of the meeting to the death of Mr. Thos. H. Powers, one of the oldest life members of the Institute, which occurred at eight o'clock this morning; when, on motion, it was

Resolved, That a committee of three be appointed by the chair, to draft a suitable minute and resolutions upon the decease of Mr. Powers, to be presented at the next meeting.

On motion, the meeting adjourned.

J. B. KNIGHT, *Secretary.*